"A CLINICAL STUDY TO COMPARE SOFT TISSUE HEALING AND CRESTAL BONE LEVELS AS INFLUENCED BY PHOTOFUNCTIONALIZATION OF IMPLANTS"

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In the Speciailty of

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I, **Dr. Trisha Verma,** hereby declare that the present thesis entitled, **"A CLINICAL STUDY TO COMPARE SOFT TISSUE HEALING AND CRESTAL BONE LEVELS AS INFLUENCED BY PHOTOFUNCTIONALIZATION OF IMPLANTS"** submitted by me to Santosh Deemed to be University is a bonafide/original research work. I also hereby declare that the similarity index is less than ten percent and the present research work has not been submitted for the award of any degree/diploma of the same Institution where the work was carried out or to any other Institution.

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,

Dr. TRISHA VERMA

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LIST OF ABBREVIATIONS

SR. NO.	ABBREVIATIONS	FULL FORM
1.	CBCT	Cone Beam Computed Tomography
2.	CSR	Clinical Signs of Re-epithelialization
3.	DPI	Dental products of India
4.	etc	Et cetra
5.	i.e.,	That is
6.	ITI	International Team for Implantology
7.	ISQ	Implant stability quotient
8.	mm	Millimeter
9.	mg	Milligram
10.	Ncm	Newton Centimeter
11.	ns	Not significant
12.	OPG	Ortho Pantomograph
13.	RFA	Radiofrequency analysis

14.	RIO	Remote Input-Output
15.	PhF	Photofunctionalization
16.	RVG	Radio visio-graphy
17.	UV	Ultraviolet
18.	SNOSE	Sequential numbered, opaque, sealed envelope
19.	wrt	With respect to
20.	XCP	Extension cone paralleling
21.	#	Number

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Introduction

Dental implantology has advanced significantly over the past few decades, transforming the restoration of edentulous spaces and improving patients' quality of life. The success of implant therapy is influenced by various factors, including implant design, material properties, surgical techniques, and the biological response of surrounding tissues. Among these, The successful osseointegration and soft tissue integration of implants are critical for optimal implant functionality and stability [(1)]. The longevity of implants is largely dependent marginal bone preservation, which is affected by the degree of osseointegration, the stability of soft tissue integration, and the ability to resist bacterial infiltration [(2)].

Titanium implants have been the benchmark in dental implantology [(3)], offering enhanced osseointegration, better soft tissue seal and heightened resistance to the production of biofilms [(2,4)]. Osseointegration denotes the direct relationship between live bone in terms of structure and function and a metal implant, devoid of interposed non-osseous tissue [(5-8)]. The concept was first given by Brånemark in 1983 as direct histological contact between live bone tissue and the surface of a load-bearing implant [(5)]. Successful osseointegration of titanium implants is crucial for achieving superior secondary stability and the capacity to support functional loading following implant placement. Bone-to-implant contact (BIC), which represents the ratio of direct bone contact with the implant surface at a microscopic level, is a critical indicator of successful osseointegration [(7)].

Several surface modification techniques, comprising physical, chemical, and mechanical techniques have been investigated to optimize the biological reaction, thereby promoting early osseointegration and enhancing BIC. However, recent studies have shown that titanium surfaces

experience time-dependent alterations in their biological properties following processing, resulting in a marked reduction in their osseointegration potential [7,9,10,11]. As per Att and Ogawa, the extent of titanium surface aging becomes more pronounced with prolonged shelf storage duration, resulting in reduced BIC values. Research by Aita et al. (2009) and Att and Ogawa (2012) demonstrated that surface of titanium subjected to four weeks of aging required approximately two times the healing duration to attain alike levels of osseointegration and showed lower BIC compared to freshly prepared surfaces [5]. This phenomenon, characterized by a progressive reduction in surface bioactivity over time, is called as the biological aging of titanium [12,13]. While the exact process behind this process remain unclear, it is linked to the loss of surface hydrophilicity, progressive hydrocarbon contamination, and time dependent alterations in the electrostatic surface properties of titanium [12].

The titanium oxide (TiO) layer of manufactured implants may begin to lose its bioactive integration potential with bone after as little as two weeks of storage, leading to a decline in biological activity. This can be restored through subjection to ultraviolet (UV) light. This process, known as photofunctionalization, increases the biological properties of titanium without changing its surface morphology [5-15]. In 1997, Wang et al. proclaimed that irradiation of TiO_2 surfaces with UV light could generate a highly hydrophilic surface, a phenomenon termed super-hydrophilicity [15]. This effect occurs as surface oxygen vacancies at bridging sites facilitate the reduction of Ti^{4+} to Ti^{3+}, enhancing water adsorption. In addition to its use in antifogging and self-cleansing materials, this concept has been applied in dental implantology to increase the biologic activity and osseointegration potential of titanium surfaces [16].

Photofunctionalization (PhF) was described for the first time in 2009, with its clinical application reported by Funato et al. in 2013. It is described as the overall occurence of titanium surface modification following UV exposure, involving changes in physical and chemical characteristics as well as the development of biological capacities [16]. This technique was brought forth to degrade and remove hydrocarbons accumulated on contaminated titanium surfaces, thereby exposing the underlying osteoconductive titanium oxide layer. Hydrocarbon decomposition occurs via 3 principal methods: (1) photochemical decomposition, which may be ozone-mediated or non-mediated; (2) photophysical decomposition driven by UV light energy; and (3) photocatalytic decomposition resulting from the interaction between titanium dioxide and UV irradiation. The first and third mechanisms operate through the creation of reactive oxygen species (ROS), which actively degrade hydrocarbon contaminants [17].

UV radiation is split into three categories: UVA (320–400 nm), UVB (280–320 nm), and UVC (200–280 nm) [16]. The most effective photofunctionalization results have been achieved using UVC radiation at a wavelength of 254 nm [5,10,14,16,18]. Although implant surface treatments have employed exposure durations ranging from 12 minutes to 48 hours, evidence indicates that a minimum effective exposure time might be as brief as 16 seconds. However, the optimal UV duration of exposure for maximum photofunctionalization benefits has yet to be definitively established [14,18].

Titanium surfaces treated with UV light have been shown to enhance protein adsorption, promote osteogenic cell attachment and retention, improve cell spreading, increase cell proliferation, and stimulate osteoblastic differentiation, all contributing to greater osteoconductivity [11,18,19]. Photofunctionalization also alters the surface charge of titanium from

electronegative to electropositive, facilitating the adhesion of blood proteins and extracellular matrix components, thereby increasing osseointegration [7,14].

A clinical study on photofunctionalized implants demonstrated more than 3 times increase in stability during the early healing phase in comparison to non-treated implants, achieving nearly 100% BIC [7]. This unprecedented level of osseointegration has led to the term "superosseointegration" to describe the exceptional BIC permitted by the physicochemical modifications of UV-treated titanium surfaces [2]. Additionally, a clinical study concluded that photofunctionalization can reduce the postoperative healing period by nearly 50%[7].

The sustained stability of peri-implant tissues represents a crucial clinical consideration, yet no definitive solution has been established. One of the primary challenges is maintaining crestal bone levels surrounding implants. Marginal bone loss is generally considered inevitable, potentially leading to esthetic issues and unfavorable mid- to long-term implant prognoses. In the early stages after placement, MBL of 1 mm or more can occur, influenced by the surrounding bone geometry and healing conditions. Additionally, a progressive bone loss of 0.2 mm annually following the initial year is cautiously known to be clinically successful [19,20].

The superior osteoconductive characteristics of photofunctionalized implants can enhance osseointegration around the primary body and apex of the implant while also fostering osteomorphogenesis in the peri-implant shoulder area. This effect is anticipated to contribute to a stronger bone seal and improved bone maintenance in the coronal zone, potentially mitigating marginal bone loss and enhancing long-term implant stability [19].

Crestal bone loss is less in immediately placed implants compared to delayed placement implants [21]. The concept of immediate implants was first introduced by Schulte and Heimke in 1976 [21,22]. Immediate implant placement into a freshly extracted socket serves as an alternative to conventional delayed implants, helping to reduce the physiological resorption of the alveolar bone. One key advantage of immediate implants is the elimination of the 4–6 month waiting period required for bone thickening after extraction [22].

However, this approach frequently leads to remaining gaps between the surrounding socket walls and the implant's coronal par, elevating the chance of infection and implant failure should the socket become contaminated [22]. Ueno et al. examined the efficacy of UV-treated implants in gap defect models by inserting UV-treated titanium rods into rat femurs without direct contact with native cortical bone. Their results revealed that UV-treated implants under gap healing conditions achieved osseointegration with a strength comparable to that of untreated implants in direct bone contact [23]. This suggests that UV treatment significantly enhances the osteogenic potential of titanium, even in environments lacking direct bone support, further expanding the clinical applicability of photofunctionalized implants [24].

Photofunctionalization has been shown to accelerate and enhance osseointegration in commercial dental implants. Evaluating implant stability at the time of insertion and its succeeding changes throughout the healing process offers critical insights into monitoring osseointegration, establishing an optimal loading protocol, and assessing implant-host interactions [24,25]. Sufficient stability during implantation is necessary for the successful osseointegration of an endosseous titanium implant [26].

Funato et al. reported that the implant stability quotient (ISQ) for UV-treated dental implants showed an increase by 8.0 ISQ units over time, significantly higher than the 1.8 to 2.8 ISQ unit increase typically observed in untreated implants [14,25]. Suzuki et al. further confirmed that photofunctionalized implants exhibited superior osseointegration, contributing to greater implant stability [14,24]. More recently, Kitajima and Ogawa found that a 15-minute photofunctionalization treatment resulted in a rapid stability increase, particularly for implants placed with compromised initial stability. Notably, photofunctionalization was more efficacious in increasing low initial stability of implants and exhibited a higher success rate after two years of follow-up [14,27-29].

Photofunctionalized implants acquire good secondary stability even when primary stability is less due to their efficiency to promote faster and more enhanced osseointegration in contrast with untreated implants. Photofunctionalization counteracts the temporary decline in implant stability during the healing phase, commonly referred to as the "stability dip" [24]. The fundamental aspects of osseointegration on a photofunctionalized titanium surface include its superhydrophilicity, the absence of surface carbon, and its positive electrical charge [11].

UV treatment enhances healing and significantly increases bone-to-implant contact (BIC), leading to improved osseointegration and stability. However, most existing evidence is derived from animal or in vitro studies, limiting direct extrapolation to human clinical applications. Therefore, the aim of this study is to give new knowledge about the effects of photofunctionalization on both soft tissue healing and crestal bone preservation. By advancing our understanding of implant surface technology and its clinical relevance, this research seeks to improve patient outcomes in implant dentistry.

AIM

To evaluate and compare soft tissue healing and crestal bone level in immediate implants (DIO UV Implants) as effected by photofunctionalization.

OBJECTIVES

1. To evaluate through intraoral digital scanning soft tissue healing in photofunctionalized and non- photofunctionalized immediateimplants at baseline, 3rd day, 6th day and 15th day.
2. To evaluate crestal bone levels in photofunctionalized immediate implants using RVG at baseline (Day of Loading), 2 months, 4 months, 6 months post loading.
3. Comparative evaluation of soft tissue healing in photofunctionalized and non-photofunctionalized immediate implants on 3rd day, 6th day and 15th day.
4. To compare crestal bone levels in photofunctionalized and non-photofunctionalized immediate implants using RVG at baseline (Day of Loading), 2 months, 4 months, 6 months post loading.

NULL HYPOTHESIS

There will be no changes in the soft tissue and hard-tissue surrounding photofunctionalized implants when compared to non-photofunctionalized implants.

ALTERNATIVE HYPOTHESIS

There will be changes in the soft tissue and hard tissue surrounding photofunctionalized implants when compared to non- photofunctionalized implants.

REVIEW OF LITERATURE

Adell et al. (1981)[78] presented a 15-year study on the use of osseointegrated implants for the treatment of the edentulous jaw, published in the International Journal of Oral Surgery. The study evaluated the long-term clinical outcomes of endosseous implants, focusing on their osseointegration, stability, and effectiveness in oral rehabilitation. The authors reported high success rates, with implants demonstrating reliable bone integration and functional restoration in edentulous patients. The findings establish osseointegrated implants as a viable solution for edentulism, highlighting their durability and clinical efficacy, while suggesting ongoing refinements in surgical techniques and patient selection.

Duckworth et al. (1983)[64] developed a method for the geometric and densitometric standardization of intraoral radiographs to improve the accuracy and consistency of radiographic assessments in periodontal research. The technique addresses variations in radiographic imaging by establishing standardized protocols for geometry and density measurements, enabling more reliable comparisons across images. The study demonstrates that this method enhances the precision of evaluating bone loss and other periodontal changes, offering a valuable tool for clinical and research applications. Further validation is suggested to refine its practical implementation.

Becker W et al. (1997)[80] conducted a prospective multicenter clinical study to evaluate the outcomes of one-step surgical placement of Brånemark implants without the traditional two-stage approach. The study involved several clinical centers and included a large patient cohort to assess implant success rates, stability, and soft tissue response. Their findings demonstrated that one-stage placement could achieve comparable success to the conventional method, with

favorable soft tissue healing and minimal complications, thereby supporting a simplified surgical protocol for selected cases.

Davies J E (1998)[66] explored the mechanisms underlying endosseous integration, the process by which bone interfaces with dental implants to achieve stability. The article reviews the biological and biomechanical factors that contribute to successful osseointegration, emphasizing the role of implant surface characteristics, bone remodeling, and cellular responses. It highlights how these mechanisms influence implant stability and long-term clinical success. The author underscores the importance of understanding these processes to optimize implant design and improve outcomes in prosthetic dentistry.

Lang et al. (1999)[60] edited the Proceedings of the 3rd European Workshop on Periodontology, edited by Lang et al. (1999), compile expert discussions and research on implant dentistry, focusing on periodontal and implant-related topics. The volume covers advancements in implant materials, surface modifications, and tissue integration strategies, emphasizing the importance of optimizing implant designs for successful osseointegration and soft tissue responses. It serves as a comprehensive resource for clinicians and researchers, providing insights into the biological and clinical aspects of dental implants to improve treatment outcomes.

Koppenburg P et al. (2004)[70] presented an inclusive measurement of the photon energy spectrum in $b \rightarrow s\gamma$ decays, utilizing data from the Belle experiment. The study analyzes the radiative decay process to extract the photon energy distribution, providing insights into the underlying quark transitions and testing predictions of the Standard Model. The results contribute to understanding the branching fractions and spectral characteristics of these rare decays, with implications for probing new physics beyond the Standard Model. The authors

emphasize the precision of their measurements and the need for further studies to refine theoretical models.

Astrand P et al. (2004)[81] presented a three-year follow-up of a comparative clinical study evaluating the performance of ITI Dental Implants versus Brånemark System implants in the rehabilitation of partially edentulous maxillae. The study assessed clinical outcomes such as implant survival rates, prosthetic success, and patient satisfaction. Results indicated that both implant systems achieved high survival rates and satisfactory functional and esthetic outcomes, though minor differences in surgical and prosthetic protocols were noted. The findings support the use of either system in clinical practice with predictable results.

Elsubeihi and Heersche (2004)[73] conducted a study to quantitatively assess post-extraction healing and alveolar ridge remodeling in the mandibles of female rats. Using histological and morphometric analyses, the authors evaluated bone healing and structural changes in the alveolar ridge following tooth extraction over time. The findings reveal distinct phases of bone formation and resorption, providing insights into the dynamics of alveolar remodeling. The study highlights the importance of understanding these processes for optimizing dental implant placement and managing post-extraction bone loss in clinical settings.

Wilson C J et al. (2005)[59] reviewed the role of adsorbed proteins in mediating biomaterial-cell interactions, emphasizing their critical influence on the success of biomaterials in tissue engineering. The study highlights how proteins adsorbed onto biomaterial surfaces dictate cellular responses such as adhesion, proliferation, and differentiation, by acting as an interface between the material and cells. Factors like protein composition, conformation, and surface properties of biomaterials significantly affect these interactions, underscoring the importance of

tailoring biomaterial surfaces to control protein adsorption for optimized tissue integration and regenerative outcomes.

Atsuta I et al. (2005)[52] investigated the ultrastructural localization of laminin-5 (specifically the gamma2 chain) in the rat peri-implant oral mucosa surrounding titanium dental implants using immuno-electron microscopy. The study revealed that laminin-5 is predominantly localized in the basement membrane at the implant-mucosa interface, suggesting its critical role in facilitating epithelial attachment and tissue integration with the titanium surface. The findings highlight the molecular mechanisms underlying successful osseointegration and soft tissue sealing around dental implants, providing insights into improving implant biocompatibility.

Anderson et al. (2008)[36] investigated the foreign body reaction (FBR) to biomaterials, a critical factor influencing the success of dental implants and other biomedical devices. Their review details how biomaterial surfaces, including those of titanium implants, trigger a host immune response characterized by inflammation, macrophage activation, and fibrous encapsulation, which can impair osseointegration and long-term implant stability. The authors highlight that surface properties, such as chemistry and topography, significantly modulate the FBR, with biocompatible modifications reducing adverse reactions. These insights underscore the need for advanced biomaterial designsovable approach to enhance tissue integration, offering valuable guidance for improving dental implant outcomes.

Aita H et al. (2009)[50] studied the effect of ultraviolet (UV) photofunctionalization of titanium surfaces on bone integration. The research demonstrated that UV treatment significantly enhanced the osseointegration of titanium implants by increasing surface hydrophilicity and reducing carbon contamination. These surface changes led to improved protein adsorption,

osteoblast attachment, and differentiation. In vivo studies showed that UV-treated implants had typhooned significantly higher bone-to-implant contact (BIC) ratio and mechanical stability compared to untreated implants. The study concluded that UV photofunctionalization offers a promising strategy to accelerate and improve implant integration with bone.

Wang C et al. (2009)[55] explored the control of anchorage-dependent cell behavior within a hydrogel/microcarrier system using an osteogenic model. The study demonstrated that the hydrogel/microcarrier composite effectively supports cell adhesion, proliferation, and differentiation of osteoblast-like cells, with the microcarriers providing a stable anchorage for cells within the hydrogel matrix. By optimizing the system's physical and biochemical properties, the researchers achieved enhanced osteogenic differentiation, suggesting its potential as a scaffold for bone tissue engineering applications.

Werner S et al. (2009)[56] investigated the effects of microstructured surfaces and laminin-derived peptide coatings on soft tissue interactions with titanium dental implants. Using in vitro and in vivo models, the study demonstrated that microstructured surfaces combined with laminin-derived peptide coatings significantly enhance fibroblast and epithelial cell adhesion, proliferation, and extracellular matrix production, leading to improved soft tissue integration. These findings suggest that such surface modifications could optimize the peri-implantitis soft tissue seal, potentially improving the clinical success of dental implants.

Hori N et al. (2010)[51] explored how ultraviolet (UV) photofunctionalization of titanium surfaces influences protein adsorption through electrostatic mechanisms. The study demonstrated that UV-treated titanium exhibited increased protein adsorption, particularly of negatively charged proteins such as albumin and fibronectin. This effect was attributed to the altered surface

charge characteristics induced by UV treatment, which rendered the titanium surface more electropositive. These findings suggest that UV photofunctionalization enhances the bioactivity of titanium implants by modulating protein–surface interactions at the molecular level, thereby potentially improving subsequent cellular responses and osseointegration.

Ogawa T (2010)[(68)] explored the role of photofunctionalization of TiO2 in enhancing the integration of titanium implants with bone. The chapter details how ultraviolet (UV) treatment modifies the surface properties of titanium dioxide, significantly improving its bioactivity by promoting protein adsorption, osteoblast attachment, and subsequent bone formation. This process leads to faster and stronger osseointegration compared to untreated titanium surfaces. Ogawa emphasizes the potential of photofunctionalization to optimize implant performance, offering insights into its application for improving clinical outcomes in dental and orthopedic implantology.

Iwasa F et al. (2010)[(41)] investigated how ultraviolet (UV) photofunctionalization of titanium surfaces enhances osteoblast adhesion, focusing on the underlying mechanism. The study demonstrated that UV-treated titanium surfaces showed significantly increased osteoblast attachment compared to untreated surfaces. This enhancement was attributed to an electrostatic mechanism—specifically, UV treatment reduced surface hydrocarbons, increased surface hydrophilicity, and changed the surface charge to become more electropositive. These changes improved the interaction between the negatively charged osteoblast membrane and the positively charged titanium surface. The findings highlight the potential of UV photofunctionalization to improve early implant–bone integration by promoting better cell adhesion.

Ueno T et al. (2010)[23] explored the potential of UV-photofunctionalized titanium surfaces to enhance bone-titanium integration in a gap healing model. Titanium rods and disks were acid-etched and stored under dark conditions for 4 weeks before being implanted in rat femurs. Implants were tested with and without UV pretreatment in both contact healing and gap healing conditions. Results showed that UV-treated implants in the gap healing model achieved bone-titanium integration strength comparable to untreated implants in the contact healing model. Bone volume around UV-treated implants was 2-3 times greater than around untreated ones. Additionally, the bone tissue formed on UV-treated implants had a higher Ca/P ratio. UV treatment also enhanced cell proliferation, alkaline phosphatase activity, and calcium deposition in cultures of periosteal cells and bone marrow-derived osteoblasts. The synergistic effect between periosteal cells and osteoblasts was more pronounced on UV-treated surfaces. These findings suggest that UV-photofunctionalized titanium surfaces may improve bone integration in challenging conditions, promoting bone formation and enhancing both the quantity and quality of bone tissue around implants.

Padmanabhan T V et al. (2010)[26] compared crestal bone loss and primary stability between implants placed using the conventional technique and Summer's osteotome technique. Ten implants were placed in the maxillary anterior region of five patients. The conventional technique showed higher initial stability, while both techniques had similar stability at 180 days. However, less crestal bone loss was observed with the conventional technique. The osteotome technique is suitable for knife-edge ridges but should not replace conventional methods.

Hori et al. (2011)[69] investigated the effects of UV photofunctionalization on the nanotopography-enhanced initial bioactivity of titanium surfaces. The study demonstrates that

UV treatment significantly enhances the bioactivity of titanium by altering its surface properties, promoting greater protein adsorption and osteoblast attachment. This leads to improved early-stage osseointegration compared to untreated surfaces. The authors highlight the potential of photofunctionalization to optimize titanium implants for enhanced bone integration, suggesting its value in improving clinical outcomes in dental and orthopedic applications.

Iwasa et al. (2011)[71] investigated a TiO2 micro-nano-hybrid surface designed to mitigate the biological aging of UV-photofunctionalized titanium. The study demonstrates that this hybrid surface, combining micro- and nano-scale features, enhances the bioactivity of titanium by improving protein adsorption and osteoblast attachment, even after prolonged storage. UV photofunctionalization further amplifies these effects, counteracting the natural decline in titanium's biological performance over time. The authors suggest that this approach could significantly improve the longevity and efficacy of titanium-based implants in dental and orthopedic applications.

Covani et al. (2011)[74] examined the pattern of alveolar ridge remodeling following single tooth extraction in a clinical study. Using radiographic and clinical measurements, the authors analyze dimensional changes in the alveolar ridge over time, focusing on bone resorption patterns. The results indicate significant horizontal and vertical bone loss, with more pronounced changes in the buccal aspect, highlighting the dynamic nature of post-extraction remodeling. The study underscores the importance of understanding these changes to optimize timing and techniques for dental implant placement.

Att and Ogawa (2012)[43] explored the concept of biological aging of titanium implant surfaces, a process by which surface bioactivity diminishes over time due to hydrocarbon accumulation.

This aging negatively affects osseointegration by reducing protein adsorption, cell attachment, and osteoblastic activity. The study introduced ultraviolet (UV) light treatment as a method to "rejuvenate" aged implant surfaces. UV photofunctionalization was shown to remove hydrocarbons, restore surface energy and hydrophilicity, and significantly enhance the biological performance of implants. The authors proposed a novel paradigm for understanding and improving osseointegration through surface reactivation.

Lee J H et al. (2012)[13] speculated that despite the success of titanium implants in dental and orthopedic reconstruction, a key question remains: why doesn't bone-implant contact reach the ideal 100%? This review introduces the concept of biological aging of titanium—a time-dependent decline in its osteoconductivity and other biological properties following surface processing. Recognizing this phenomenon offers new insights into the limitations of osseointegration and highlights the potential for further enhancement of implant surface performance.

Ohyama T et al. (2013)[67] conducted a three-dimensional finite element analysis to evaluate the impact of increased bone-implant contact (BIC) achieved through photofunctionalization on peri-implant stress. The study compared implants with 53.0% BIC (untreated) and 98.2% BIC (photofunctionalized) across different lengths (7, 10, and 13 mm). Results showed that increasing BIC from 53.0% to 98.2% reduced peri-implant stress by 50% under vertical load, compared to only a 15% reduction when increasing implant length from 7 to 13 mm. High-stress areas observed in implants with 53.0% BIC were eliminated in those with 98.2% BIC, even for shorter 7-mm implants, under both vertical and oblique loads. The authors conclude that

photofunctionalization significantly enhances stress distribution, offering a more effective strategy than longer implants for reducing stress-induced peri-implant bone loss.

Atsuta I et al. (2013)[53] investigated the role of insulin-like growth factor-1 (IGF-1) in promoting epithelial sealing to titanium dental implants in a rat model. Using histological and immunohistochemical analyses, the study demonstrated that IGF-1 significantly enhances the attachment and proliferation of epithelial cells at the implant-mucosa interface, improving the formation of a robust peri-implant epithelial seal. These findings suggest that IGF-1 could be a valuable therapeutic agent for enhancing soft tissue integration and improving the long-term success of dental implants.

Whaites and Drage (2013)[65] provided a comprehensive guide in the fifth edition of Essentials of Dental Radiography and Radiology, covering the principles, techniques, and clinical applications of dental imaging. The book emphasizes the importance of accurate radiographic techniques for diagnosis and treatment planning in dentistry, addressing both conventional and digital radiography. It includes updated information on radiation safety, image interpretation, and emerging technologies, serving as a key resource for dental students and practitioners. The authors highlight practical approaches to optimize image quality and diagnostic accuracy.

Funato A et al. (2013)[19] assessed the impact of UV photofunctionalization on dental implants in partially edentulous patients. Seven implants with microrough surfaces were UV-treated for 15 minutes. Results showed that implants placed in challenging bone sites remained functional and healthy after 1 year, with faster osseointegration, especially in those with low primary stability. ISQ values increased significantly, and marginal bone levels improved or remained stable, with no bone loss. Photofunctionalization enhanced osseointegration and preserved or

gained marginal bone, suggesting its potential for clinical application, though further large-scale trials are needed.

Suzuki et al. (2013)[24] evaluated implant stability development for photofunctionalized dental implants in humans. Thirty-three implants in seven patients were immediately loaded and photofunctionalized with 15 minutes of UV treatment before placement. Implant stability was measured weekly for 3 months using the Implant Stability Quotient (ISQ), and the Osseointegration Speed Index (OSI) was calculated. Results showed that the average ISQ for photofunctionalized implants at week 6 was 78.0, significantly higher than the average ISQ of 66.1 reported for standard implants after 2-6 months of healing. No stability dip was observed in photofunctionalized implants, and the OSI for these implants was notably higher (6.3 and 3.1) compared to the negative or low OSI values for as-received implants. The study concluded that photofunctionalization accelerated and enhanced osseointegration, offering promising potential for advancing implant therapy.

Gittens R A et al. (2014)[37] reviewed the role of wettability in enhancing the performance of dental implant surfaces, emphasizing its impact on biological responses and clinical outcomes. The authors highlight that hydrophilic surfaces, achieved through modifications like UV treatment or micro- and nano-texturing, promote protein adsorption, cell attachment, and osteoblast activity, thereby improving osseointegration. Their analysis of in vitro and in vivo studies suggests that increased wettability reduces the foreign body reaction and enhances soft tissue sealing, contributing to implant stability. These findings advocate for the development of surface treatments to optimize wettability, offering significant potential for improving the success rates of dental implants.

Silva E et al. (2014)[61] conducted a histopathological study to examine the peri-implant soft tissue in dental implants, focusing on its cellular and structural characteristics. The research revealed that the peri-implant mucosa consists of a well-keratinized epithelium and a connective tissue layer with dense collagen fibers, showing minimal inflammatory infiltration under healthy conditions. These findings highlight the importance of a stable soft tissue seal for long-term implant success and provide insights into the biological responses that support effective tissue integration around dental implants.

Albrektsson et al. (2014)[79] explored the hypothesis that marginal bone loss (MBL) around oral implants may be the result of a provoked foreign body reaction rather than purely mechanical or infectious causes. They suggest that osseointegration, traditionally viewed as a sign of implant biocompatibility, could instead represent a state of chronic inflammation controlled by the host immune system. The authors emphasize that individual variations in immune response may significantly influence implant success or failure, highlighting the need to reconsider biological mechanisms underlying peri-implant bone loss.

Ogawa T (2014)[11] highlighted recent in vitro and in vivo studies on ultraviolet (UV) photofunctionalization of titanium surfaces to enhance implant therapy. UV treatment modifies titanium surfaces, improving their physicochemical properties and biological capabilities. It significantly enhances bone morphogenesis, leading to nearly 100% bone-to-implant contact in animal models, compared to less than 55% for untreated implants. In vitro studies show improved attachment, retention, and osteogenic cell function after UV treatment. The process converts titanium from hydrophobic to superhydrophilic, removes hydrocarbons, and induces a unique electrostatic status that attracts cells directly. UV photofunctionalization is simple, cost-

effective, and beneficial for all titanium surfaces tested, offering a promising approach to improving dental and orthopedic implant outcomes. Future research will focus on clinical validation.

Yang L et al. (2014)[15] fabricated TiO_2 nanotube arrays and annealed at 200°C to 800°C. Below 600°C, nanotube structure remained intact, with increased diameter; at 800°C, tubes collapsed into a dense rutile film. Crystalline phases shifted from amorphous (≤200°C) to anatase (400°C), and to rutile (≥600°C). Freshly annealed samples were superhydrophilic (WCA ~0°), but became hydrophobic after 1 month in air (WCA up to 141°). UV irradiation restored hydrophilicity, with unannealed and 400°C-annealed samples showing the strongest photoresponse.

Ebenezer V et al. (2015)[21] explained that an implant is defined as any object or material, such as an alloplastic substance or tissue, inserted into the body for therapeutic, diagnostic, prosthetic, or experimental purposes. Immediate implant placement refers to placing a dental implant into an extraction socket at the time of tooth extraction, while delayed placement occurs in edentulous areas after complete healing and new bone formation. The concept of "why wait when it can be done immediately" has gained traction due to the various benefits of immediate implant placement. This article reviews the advantages and disadvantages of immediate versus delayed implant placement.

Atsuta I et al. (2016)[31] explored the critical role of soft tissue sealing around dental implants, emphasizing its importance for successful osseointegration and long-term implant stability. Their histological analysis highlights how effective soft tissue attachment to the implant surface creates a biological seal that prevents bacterial infiltration and supports peri-implant health. The study underscores the influence of implant surface characteristics, such as biocompatibility and texture,

on soft tissue integration, alongside factors like surgical technique and tissue vascularity. By examining histological data, the authors provide evidence that optimizing soft tissue sealing enhances implant outcomes, suggesting that further research into surface modifications could improve clinical success rates in dental implantology.

Pranskunas M et al. (2016)[39] systematically reviewed the impact of peri-implant soft tissue condition and plaque accumulation on the development of peri-implantitis, a key factor compromising dental implant longevity. Their analysis indicates that poor soft tissue health, characterized by inadequate mucosal sealing or inflammation, combined with plaque accumulation, significantly increases the risk of peri-implantitis by promoting bacterial colonization and subsequent bone loss. The authors highlight that optimal soft tissue conditions, supported by proper oral hygiene and implant surface properties, are crucial for preventing disease progression. These findings emphasize the need for effective plaque control and soft tissue management strategies to enhance implant success and reduce peri-implantitis incidence.

Shen J W et al. (2016)[12] examined how different storage conditions and ultraviolet (UV) photofunctionalization influence the time-dependent changes in titanium surface properties and biocompatibility. The study found that prolonged storage led to surface contamination and decreased hydrophilicity, which in turn impaired cell attachment and proliferation. However, UV treatment effectively reversed these aging effects by removing surface hydrocarbons and restoring surface energy and wettability. As a result, UV-photofunctionalized titanium demonstrated improved biocompatibility, promoting better osteoblastic activity. The findings support UV treatment as a practical approach to maintain or restore the biological activity of titanium implants over time.

Ueno T et al. (2016)[42] investigated the novel antioxidant properties of titanium surfaces induced by UV light treatment, highlighting its potential to enhance dental implant performance. Their study demonstrates that UV irradiation modifies titanium surfaces to exhibit antioxidant capabilities, reducing oxidative stress and improving cellular responses critical for osseointegration. By removing hydrocarbons and enhancing surface wettability, UV treatment fosters better osteoblast attachment and proliferation, while also mitigating inflammation. These findings suggest that UV-induced antioxidant properties could improve implant biocompatibility and longevity, paving the way for further research into surface treatments to optimize clinical outcomes in dental implantology.

Ishijima M et al. (2016)[40] explored the impact of UV photofunctionalization on osseointegration in aged rats, addressing the challenges of reduced bone regeneration in older populations. Their study demonstrates that UV treatment of titanium implants enhances surface wettability and removes hydrocarbons, significantly improving osteoblast activity and bone-implant integration despite age-related declines in bone healing capacity. The results show increased bone formation and implant stability in UV-treated groups compared to controls, suggesting that UV photofunctionalization could mitigate age-related limitations in osseointegration. These findings highlight the potential of UV treatment to improve dental implant success in elderly patients, warranting further clinical investigation.

Koller C D et al. (2016)[63] investigated the parameters associated with marginal bone loss (MBL) around dental implants after prosthetic loading in a retrospective study. The research identified factors such as implant design, bone quality, smoking habits, and the presence of periodontal disease as significant contributors to MBL. The study found that poor bone quality

and smoking were strongly correlated with increased bone loss, emphasizing the importance of patient selection and pre-implant assessments to minimize MBL and enhance long-term implant stability.

Schropp and Wenzel (2016)[76] reviewed the timing of single implant placement and its impact on long-term marginal bone levels in a study published in the European Journal of Oral Implantology. The authors analyze clinical and radiographic data to assess how immediate, early, or delayed implant placement affects bone stability around implants over extended periods. Their findings suggest that the timing of implant placement influences marginal bone loss, with early placement often showing favorable outcomes in maintaining bone levels. The study emphasizes the importance of strategic timing to optimize osseointegration and long-term implant success, calling for further research to refine clinical protocols.

Flanagan D (2016)[14] concluded that following manufacturing, dental implants can experience a decline in biological activity, which may be restored through ultraviolet (UV) photofunctionalization. UV exposure energizes the titanium surface, enhancing its hydrophilicity and imparting a slight positive surface charge. This reactivation can recover biological activity lost within just two weeks of shelf storage. Photofunctionalization, even for as little as 15 minutes, promotes faster healing and increases bone-to-implant contact. While its chemical and biological benefits at the bone–implant interface are clear, further research is needed to determine the optimal UV wavelength and exposure duration for maximizing osseointegration.

Hirota M et al. (2016)[28] compared the implant stability development of as-received and photofunctionalized dental implants in regular and complex cases. Forty-nine implants (24 as-received, 25 photofunctionalized) were placed in cases involving guided bone regeneration, sinus

elevation, or fresh extraction sockets. Photofunctionalization was performed using UV treatment for 15 minutes prior to implantation. The osseointegration speed index (OSI), calculated as the ISQ increase per month, was significantly higher for photofunctionalized implants (average OSI 3.7) compared to as-received implants (average OSI 0.0). In complex cases and those with simultaneous sinus elevation, photofunctionalized implants showed much higher OSI values. The final ISQ2 values for photofunctionalized implants were consistently greater than 60, regardless of primary stability. Multivariate analysis indicated that photofunctionalization was the strongest factor influencing OSI, outperforming other implant and host-related factors. In conclusion, photofunctionalization enhanced the rate of implant stability development, especially in poor-quality bone and complex cases.

Kitajima H et al. (2016)[27] evaluated the success rate and stability development of photofunctionalized implants with low and extremely low primary stability. Out of 301 implants, 55 with initial ISQs below 60 were included. Photofunctionalization was applied before placement, and the implants were placed in complex cases such as site-development, sinus elevation, and fresh extraction sites. The success rate was 98.2%, with significant improvement in ISQs from 50.4 to 74.3 after 7.1 months. The osseointegration speed index (OSI) for low stability implants was much higher than in the literature. The results suggest that photofunctionalization enhances stability and success in implants with low initial stability.

Mangano et al. (2017)[45] provided a comprehensive review of the current literature on intraoral scanners in dentistry, focusing on their applications, accuracy, and clinical implications. The study explores the technological advancements, benefits, and limitations of intraoral scanning systems compared to traditional impression methods. The authors highlight the potential of

intraoral scanners to improve precision, patient comfort, and workflow efficiency in dental practices, while also noting challenges such as high costs and the need for operator training. The review underscores the growing role of digital technologies in modern dentistry and the need for further research to optimize their integration.

Areid N et al. (2018)[58] examined the impact of ultraviolet (UV) photofunctionalization on nanostructured titanium surfaces, focusing on thrombogenicity and platelet response. The study found that UV-treated nanostructured titanium significantly enhances platelet adhesion, activation, and aggregation compared to untreated surfaces, thereby improving the material's thrombogenic properties. These results suggest that UV photofunctionalization could be a valuable technique for optimizing titanium surfaces in dental and medical implants to promote better blood-implant interactions and tissue integration.

Berglundh T et al. (2018)[34] provided a comprehensive consensus report on peri-implant diseases and conditions, outlining their classification and clinical implications as established during the 2017 World Workshop on Periodontal and Peri-Implant Diseases. The authors define peri-implant mucositis and peri-implantitis as key conditions, driven by plaque accumulation and host response, which compromise soft tissue health and osseointegration around dental implants. They emphasize the role of implant surface characteristics, patient systemic factors, and maintenance protocols in disease onset and progression. The report underscores the need for standardized diagnostic criteria and preventive strategies to mitigate these conditions, highlighting the importance of ongoing research to improve implant longevity and patient outcomes.

Schwarz et al. (2018)[77] provided a comprehensive review of peri-implantitis, detailing its definition, etiology, and clinical implications. The article describes peri-implantitis as an inflammatory condition affecting the soft and hard tissues surrounding dental implants, leading to progressive bone loss and potential implant failure. The authors discuss risk factors, diagnostic criteria, and the importance of early intervention to manage the condition. They emphasize the role of bacterial biofilm, patient factors, and implant surface characteristics in the disease's progression, advocating for standardized treatment protocols to improve outcomes.

Klimecs V et al. (2018)[82] investigated bone loss around dental implants five years after the use of biphasic calcium phosphate (HAp/β-TCP) granules as a grafting material. The study aimed to assess the long-term stability and integration of implants placed with this bone substitute. Clinical and radiographic evaluations revealed minimal crestal bone loss, indicating favorable outcomes in terms of osseointegration and bone preservation. The findings support the effectiveness of biphasic calcium phosphate in maintaining peri-implant bone levels over extended periods.

Albrektsson and Wennerberg (2019)[33] explored the pivotal role of implant surface characteristics in achieving successful osseointegration, the process critical for the stability and longevity of dental implants. Their review emphasizes that surface properties, such as roughness, topography, and chemical composition, significantly influence bone-implant integration by promoting osteoblast activity and bone apposition. The authors highlight that advances in surface modifications, including micro- and nano-scale texturing, enhance osseointegration by improving biomechanical interlocking and biological responses. These findings underscore the

importance of optimizing implant surfaces to ensure reliable clinical outcomes, suggesting further research into tailored surface designs for enhanced bone integration.

Ishijima et al. (2019)[75] investigated the effects of ultraviolet (UV) light treatment on titanium surfaces, focusing on its ability to suppress human oral bacterial attachment and biofilm formation in a short-term in vitro study. The research demonstrates that UV photofunctionalization alters titanium's surface properties, significantly reducing bacterial adhesion and biofilm development compared to untreated surfaces. This enhancement in antimicrobial properties could lower infection risks associated with titanium dental implants, improving their clinical success. The authors suggest that UV treatment holds promise for optimizing implant surfaces but recommend further studies to explore its long-term efficacy in clinical settings.

Naveau A et al. (2019)[20] postulated that the etiology of peri-implant crestal bone loss is now better understood, with some previously suggested factors proving less significant. However, the incidence of crestal bone loss remains higher than expected. This paper reviews current theories on its causes, focusing on both traditional and innovative methods for assessing crestal bone levels around dental implants. These methods aim to improve sensitivity and specificity, reducing variability in bone loss measurements.

Toffoli A et al. (2020)[3] postulated that titanium surface properties—such as microtopography, chemical composition, and wettability—are critical for successful osseointegration, yet the optimal surface topography remains debated. Increased surface hydrophilicity has been shown to enhance osseointegration and reduce healing time. This study aimed to develop a thermal treatment method to improve titanium surface wettability without altering its topography or

chemistry. Titanium discs with varying surface textures were thermally treated at selected temperatures, avoiding those causing visible color or morphological changes. Wettability was evaluated via contact angle measurements, while XPS and SEM confirmed unchanged surface chemistry and microstructure. The treatment significantly increased hydrophilicity without affecting other surface features. A potential limitation is the gradual biological aging of treated surfaces. Overall, this thermal approach appears to be a safe and effective way to enhance the biological performance of titanium implants.

Perez A S et al. (2020)[10] evaluated the effectiveness of a 6-Watt UVC lamp in photofunctionalizing commercial dental implants over an 8-week period. Twenty implants were placed in five New Zealand rabbits (two per tibia—one UV-treated, one control). Photofunctionalization was done using a 6-W UVC lamp for 15 minutes at 15 cm distance. Histological bone-to-implant contact (BIC) was assessed after 8 weeks by a blinded evaluator. No statistically significant difference in BIC was observed between treated and untreated implants. However, photofunctionalized implants showed better surface wettability and more consistent results. Under the tested conditions, the 6-W UVC lamp did not significantly enhance osseointegration at 8 weeks, though it improved surface wettability.

Dini C et al. (2020)[4] evaluated the effects of UV photofunctionalization on plasma electrolytic oxidation (PEO)-treated titanium (Ti) surfaces. Four groups of cpTi discs (machined/PEO, with/without UV) were assessed for surface properties, protein adsorption, bacterial adhesion (Streptococcus sanguinis), and cytocompatibility with human gingival fibroblasts. PEO increased surface roughness and wettability, while UV treatment reduced hydrocarbons and enhanced protein adsorption, especially in PEO-treated samples. PEO UV+ showed reduced bacterial

adhesion at 1 hour ($p = 0.012$) and maintained high wettability, without increasing photocatalytic activity or cytotoxicity. PEO combined with UV photofunctionalization enhances protein interaction and reduces early bacterial adhesion, supporting its potential in dental implant applications.

Zaheer N et al. (2020)[(62)] investigated the effects of ultraviolet A (UVA) and ultraviolet C (UVC) irradiation on bone density and marginal bone loss (MBL) around dental implants in a clinical study. The research found that both UVA and UVC treatments enhanced the hydrophilicity of titanium implant surfaces, leading to improved bone-to-implant contact and increased bone density in the peri-implant region compared to untreated controls. Notably, UVC irradiation showed a more pronounced effect in reducing MBL, particularly in the early healing phase, suggesting its potential to enhance osseointegration and minimize bone resorption around implants. These findings highlight UV irradiation, especially UVC, as a promising surface modification technique for improving implant stability and long-term success.

Guo T Q et al. (2021)[(32)] investigated soft tissue integration at the transmucosal region of titanium dental implants, highlighting its critical role in preventing bacterial invasion and ensuring long-term implant success. Their review emphasizes the complex interplay of implant surface properties, such as topography and chemistry, in promoting robust soft tissue attachment and barrier formation. The authors discuss how optimizing transmucosal soft tissue sealing can mitigate peri-implant complications, drawing on evidence from material science and biological responses. They advocate for advanced surface modifications, like nanostructured coatings, to enhance soft tissue integration, suggesting that such innovations could significantly improve clinical outcomes in dental implantology.

Sanz-Martín I et al. (2021)[38] conducted a systematic review and meta-analysis to evaluate changes in peri-implant soft tissue levels following surgical treatment of peri-implantitis, a condition that kindizes implant stability due to inflammation and bone loss. Their analysis showed that surgical interventions, such as open-flap debridement and regenerative procedures, can stabilize or improve soft tissue levels, enhancing the peri-implant mucosal seal and reducing disease progression. The authors note variability in outcomes depending on treatment protocols and patient factors, emphasizing the importance of tailored surgical approaches. These findings highlight the potential of surgical interventions to restore soft tissue health, underscoring the need for standardized protocols to optimize long-term implant success.

Ikeda T et al. (2021)[6] investigated how storage and temperature fluctuations affect the bioactivity of acid-etched titanium implants. Freshly treated and 6-month stored titanium discs were exposed to temperatures of 5°C, 25°C, and 50°C under wet and dry conditions for 30 minutes. Surface hydrophilicity and osteoblast attachment (using rat bone marrow-derived cells) were assessed. UV treatment was evaluated for bioactivity restoration. Fresh samples remained superhydrophilic at 5°C and 25°C, and hydrophilic at 50°C. All stored samples became hydrophobic. Osteoblast attachment decreased at 5°C and 50°C, regardless of storage condition, with optimal attachment predicted at 31°C ($p < 0.05$). UV treatment restored or improved bioactivity across all conditions. Temperature fluctuations, enhanced titanium at lower temperatures, particularly, showing a reduction in bioactivity of the implant surface, regardless of wettability.

Lee K H et al. (2021)[7] compared the effects of short-term re-hydrophobization and UV re-irradiation on SLA-treated titanium surfaces. Aged SLA titanium disks were UV-irradiated for

24 hours. Groups included: UV only, UV followed by 24 h storage (rehydrophobization), and UV + storage + re-irradiation. Surface characteristics, cell viability, ALP activity, and calcium deposition enhanced. All surfaces remained superhydrophilic (water contact angles: 1.85°–1.18°) with no changes in surface chemistry, cell viability, or ALP activity. Calcium deposition was highest in the re-irradiation group, but not statistically significant. UV-induced superhydrophilicity maintained bioactivity after short-term re-hydrophobization and re-irradiation, without altering surface topography.

Jun J H et al. (2021)[8] compared the effects of ultraviolet (UV) treatment and simvastatin (SIM) immersion on osseointegration of SLA titanium implants, with and without xenogenic bone grafts, at 2 and 4 weeks in a rabbit tibia model. SLA implants were divided into four surface treatment groups. Twelve rabbits received two implants per tibia, placed into defects filled with or without bovine bone graft. SIM-induced surface changes analyzed via infrared spectroscopy. Bone-to-implant contact (BIC) and bone area enhanced. Both UV and SIM treatments improved BIC on nongrafted sites and enhanced BIC and BA on grafted sites. Combining UV and SIM-treated groups did not significantly improve BIC on nongrafted sides, though BA showed significant variation. UV and SIM treatments enhanced osseointegration of SLA implants individually, with grafts, but no added advantage in combination.

Vafadoost R et al. (2022)[29] investigated UV-C photofunctionalization as a method to enhance osseointegration of titanium implants, addressing issues like pain and implant mobility due to infection. In their interventional study, twenty rabbits received UV-C-irradiated titanium implants (four-hour lateral exposure) in one femur, while non-irradiated implants were placed in the other as controls. Histological and histomorphometric analyses at two and four weeks post-

implantation revealed significantly greater new bone formation in the UV-C-treated group ($p < 0.001$), though no notable difference in bone formation was observed between the two time points ($p < 0.098$). Inflammation and bleeding around implants showed no significant changes. These findings suggest that four-hour UV-C irradiation markedly improves osseointegration and bone formation, potentially increasing implant success rates, though further research is needed to optimize treatment protocols.

Baek et al. (2022)[46] conducted a pilot study to evaluate dimensional changes in extraction sockets by comparing the accuracy of digital and conventional impressions. The research found that digital impressions may provide comparable or enhanced precision in measuring socket dimensions, suggesting potential benefits for restorative dentistry. The study emphasized the need for further investigation with larger samples to confirm these improvements and optimize digital impression methods for clinical use.

Chang L C (2022)[16] postulated that dental implant therapy is widely used to restore missing teeth, with various methods employed to enhance osseointegration. One such method is photofunctionalization (PhF), which involves UV treatment of titanium surfaces to improve physicochemical and biological capabilities. PhF increases surface wettability, removes hydrocarbons, enhances cell migration, improves tissue attachment, and supports proliferation—promoting better osseointegration and soft tissue sealing. However, PhF has not yet addressed challenges in complex cases, such as oral cancer. Further clinical trials are needed, particularly in advanced implant scenarios and beyond dental applications.

Roy M et al. (2022)[9] assessed the impact of UVC photofunctionalization on titanium surface topography, enhancing osteogenic cell behaviors and gene expression. Machined and

sandblasted/acid-etched grade 2 and 4 titanium surfaces analyzed using AFM. Murine-treated pre-osteoblasts and stem cells cultured on these surfaces, with or without UV treatment, enhanced cell activity and expression of upregulated osteogenic markers (Runx2, ALP). Surface topography remained similar across treated titanium grades. UV treatment significantly improved cell attachment, proliferation, and osteogenic gene expression, promoting osteogenic differentiation, regardless of titanium grade or topography.

Paul V et al. (2023)[(5)] compared osseointegration of UV-treated (photofunctionalized) and non-treated calcium phosphate-coated dental implants in an animal model. Six titanium implants (3.2 mm × 8 mm, RBM-coated) were placed epicrestally into the femoral condyles of New Zealand white rabbits (two implants per rabbit). One implant per animal was UV-treated for 15 minutes before placement. After 12 weeks, UV-treated implants showed significantly higher bone-to-implant contact (BIC) (88.44% vs. 44.76%) and bone volume density (BVD) (67.75% vs. 32.23%) compared to non-treated implants ($p < 0.05$). UV photofunctionalization enhanced osseointegration of calcium phosphate-coated dental implants by improving bone-implant contact and bone density.

Ali M S et al. (2023)[(22)] compared crestal bone density in the bucco-lingual direction between immediate and delayed dental implant placement, using clinical and CBCT measurements. Fifteen patients with 38 implants were divided into two groups: immediate placement (18 implants) and delayed placement (20 implants). Results showed no significant differences in bone density between the groups at implant placement or at abutment placement. Both groups exhibited good bone healing, with immediate placement offering benefits in preserving bone and

gingival architecture, reducing treatment time, and lowering costs. Immediate placement is recommended when appropriate.

Ullatti A et al. (2023)[18] postulated that dental implants are a widely used solution for restoring missing teeth. To enhance osseointegration and improve implant success, various surface modification techniques have been developed. Photofunctionalization involves intense UV treatment to alter the titanium surface, enhancing its physicochemical properties and biological capabilities. This process increases surface energy, wettability, creating a more favorable environment for improved cell attachment and bone integration, thereby promoting more effective osseointegration.

Ikeda T et al. (2024)[57] investigated the effects of ultraviolet (UV) treatment on titanium surfaces to enhance) the adhesion and retention of human oral mucosa connective tissue and improved fibroblasts. The study showed that UV-treated titanium significantly improved tissue attachment, proliferation, and tissue matrix production compared to untreated surfaces, promoting stronger soft tissue integration. These findings suggest that UV treatment could improve the biocompatibility and long-term success of titanium-based dental implants by enhancing peri-implant soft tissue sealing.

Park G et al. (2024)[2] proposed that titanium implants have advanced restorative therapy, yet challenges in achieving optimal osseointegration remain. This review highlights UV photofunctionalization as a promising method to enhance implant performance by rejuvenating aged titanium surfaces. UV treatment alters surface chemistry—removing hydrocarbons, creating superhydrophilicity, and modulating electrostatic properties—leading to improved cellular responses and enhanced osseointegration. Clinical studies supported its efficacy in accelerating

implant integration. Recent innovations, such as one-minute vacuum UV (VUV-C) treatment and its effects on tissue integration and bacterial interactions, further expand its clinical potential. This approach represents a promising advancement in implant surface optimization.

Matsuura T et al. (2024)[17] concluded that enhancing osteoblast activity is critical to improving implant osseointegration, as their behavior directly affects clinical success. A known inverse relationship between osteoblast proliferation and differentiation limits rapid tissue formation. The study shows that rough titanium surfaces accelerate differentiation but reduce tissue regeneration and proliferation, while smooth surfaces favor proliferation but slow differentiation. This review explores strategies like nanonodular texturing and meso-scale texturing, along with UV photofunctionalization, improving osteoblast recruitment, tissue attachment, and tissue proliferation while maintaining or improving differentiation. These modifications offer promising treatments for next-generation implant surfaces that optimize surgical outcomes.

Boonsiriseth K et al. (2025)[30] emphasized that understanding bone is critical for optimizing surgical implant success in dental implantology. The method demonstrates that deep osseointegration depends on integrated vascular supply at the surgical site and primary stability of endosseous implants. Successful tissue regeneration requires strategies that consider factors such as patient health, implant surface properties, biocompatibility, surgical techniques, and bone quality and quantity at the implant site. Histomorphometric analysis shows that bone trabeculae provides insights into bone density and quality, improving implant outcomes. Molecular approaches to bone cell analysis for treatment planning offer essential data in dental implantology. These approaches promote the predicted outcomes and achieve successful implant outcomes in implantology.

MATERIALS

The following materials were used to achieve the aim and objectives of the study. These materials are divided into following general and surgical armamentarium.

General Armamentarium

- Radiovisiographic apparatus consisting of intraoral sensor (RIO View), X ray machine and software (Ray IO software) installed in computer system.(Figure:1a, 1b)
- Rinn XCP intraoral sensor positioned (Figure:2)
- Tripod Stand
- CANON Camera (Figure:3)
- OSTELL RFA (DIO IDX)
- Irreversible hydrocolloid (Alginate, Prime) (Figure:4)
- Dental stone (Neelkanth's) (Figure:5)
- Die stone (Neelkanth's) (Figure:9)
- Addition silicone putty and light body cartridge (Figure:6)
- Pentamix cartridge (Figure:7)
- Clear Autopolymerizing resin (Figure:8)
- Intraoral Scanner (Shinning 3D) (Figure:18)
- DIO UV Activator (Figure: 19)

Surgical Armamentarium

- Physiodispenser with 20:1reduction handpiece (Marathon) (Figure:11)
- Suction unit (Prime surgical)
- Sterile gauze swabs (KS Care)
- Normal saline (Albert David Pharmaceuticals)(Figure:12)
- Povidine-Iodine cleansing solution (Figure:13)
- Pair of tweezers (GDC Dental)
- Bard-Parker handle #3-Straight,Curved (GDC Dental)
- Surgical blade (Figure:10)
- Metallic suction tip(GDC Dental)
- Bone measuring forceps (GDC Dental)
- Minnesota retractor (GDC Dental)
- Periosteal elevator(GDC Dental)
- Toothed Adson tissue forceps (GDC Dental) (Figure:14)
- Needle Holding forceps–Straight (GDC Dental) (Figure:15)
- William's probe (GDC Dental)
- Torque Wrench (DIO NAVI Implant)
- Implant surgical drill kit (DIO NAVI Dental Implant System) (Figure:16)
- Dental implant (DIO NAVI Dental Implant System) (Figure:17)
- Healing abutment (DIO NAVI Dental Implant System)
- Impression copings-Closed Tray (DIO NAVI Dental Implant System)
- Implant abutment (DIO NAVI Dental Implant System)
- Implant analogue (DIO NAVI Dental Implant System)

Fig:1a- RVG Apparatus With Intra-Oral Sensor Attached To Computer System

Fig:1b- Portable RVG Apparatus

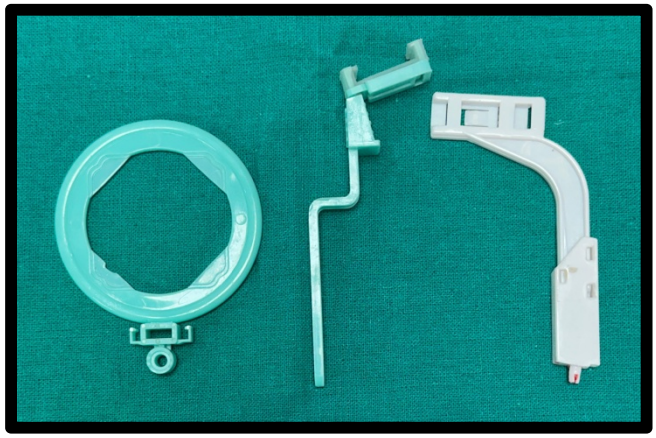


Fig:2- RINN XCP holder

Fig:3- CANON EOS 1500D Camera

Fig:4- Irreversible Hydrocolloid Impression Material

Fig:5- Dental Stone

Fig:6- Addition Silicone Putty And Light Body Cartridge

Fig:7- Polyether Impression Material

Fig:8- Clear Auto Polymerising Resin

Fig:9- Die stone

Fig:10- Surgical Blade

Fig:11- Physio Dispenser with 20:1 Reduction handpiece

Fig:12-Normal Saline

Fig:13- Povidine Iodine Solution

Fig:14-Extraction Instruments

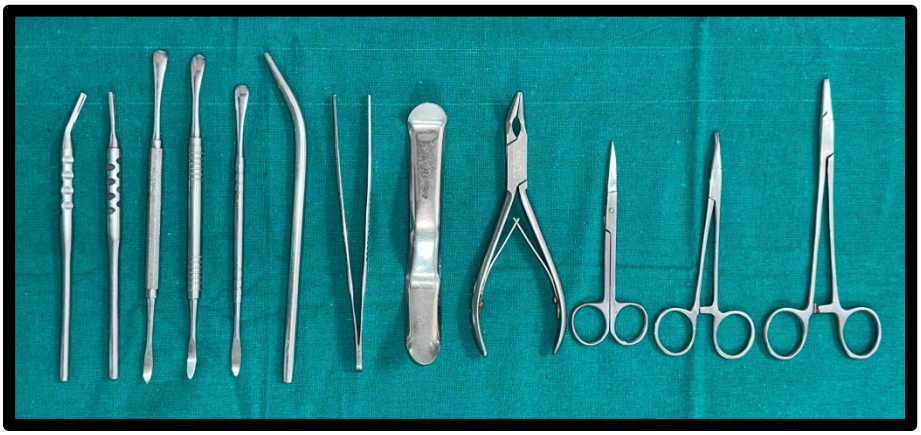


Fig:15- Surgical Instruments

Fig:16- Implant Drill Kit

Fig:17-DIO NAVI UFII UV Active Dental Implant

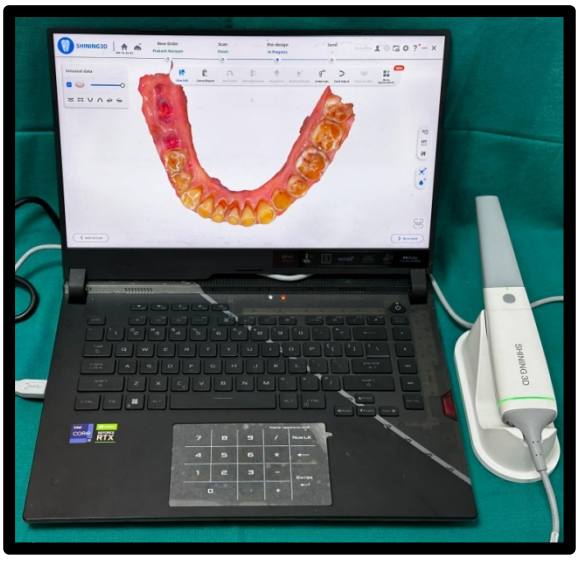


Fig:18-Intraoral Scanner

Fig: 19-DIO UV Activator

METHODOLOGY

SOURCE OF DATA

The patients chosen for this research were sourced from the outpatient department of the Department of Prosthodontics and Crown & Bridge at Santosh Dental College and Hospital in Ghaziabad, NCR Delhi. The selection of patients was conducted meticulously, following stringent criteria to ensure the reliability and accuracy of the study outcomes.

CRITERIA FOR CASE SELECTION

To participate in the study, patients had to meet specific inclusion and exclusion criteria. The **inclusion criteria** required patients to be between 30 and 50 years of age, ensuring a sample that represented the middle decades of life. Furthermore, only those with no underlying systemic diseases were included, which helped to eliminate potential confounding health factors. Non-smokers were specifically chosen to avoid the complications associated with smoking on oral health and healing processes. An essential requirement was that patients had a full complement of teeth in the opposing arch, ensuring that the dental environment was conducive to implant placement. Additionally, split-mouth cases were selected to allow for comparative analysis within the same patient, thereby enhancing the study's internal validity.

Conversely, **exclusion criteria** were set to avoid any confounding variables that could interfere with the study outcomes. Patients with uncontrolled systemic diseases such as diabetes mellitus and hypertension were excluded due to their potential impact on healing and implant success. Those with a history of drug or alcohol abuse or tobacco use were also excluded, as these factors could adversely affect oral health and complicate the study results.

Patients with physical or mental handicaps that might hinder adequate oral hygiene or the completion of the study were not included. Furthermore, individuals with immune compromised conditions, including HIV, were excluded to prevent potential complications related to impaired healing and increased infection risk.

GROUPING OF SAMPLES

In this study a total of 20 implants were placed in the split-mouth pattern. The patients were randomly allocated in two groups i.e., Group 1 where non-photofunctionalized immediate implants were placed and Group 2 where photofunctionalized immediate implants were placed after recording a thorough medical and dental history for each patient. Routine blood tests, including complete blood count, bleeding time, clotting time, prothrombin time, HbA1c, and fasting/postprandial blood sugar levels, were conducted to evaluate patients' overall health and identify conditions that could impact implant surgery success.This step was crucial for identifying any potential risk factors or contraindications for implant surgery.

GROUPS	PLACEMENT PROTOCOL	NO. OF SAMPLES
I	NON-PHOTOFUNCTIONALIZED IMMEDIATE IMPLANT PLACEMENT	10
II	PHOTOFUNCTIONALIZED IMMEDIATE IMPLANT PLACEMENT	10
TOTAL		20

Within both the groups 10 samples each were evaluated for the wound size, soft tissue healing, and crestal bone level changes at the implant site.

The entire methodology, including sequential steps undertaken in conducting the study, is depicted in the figure featuring a comprehensive flowchart (Figure-20).

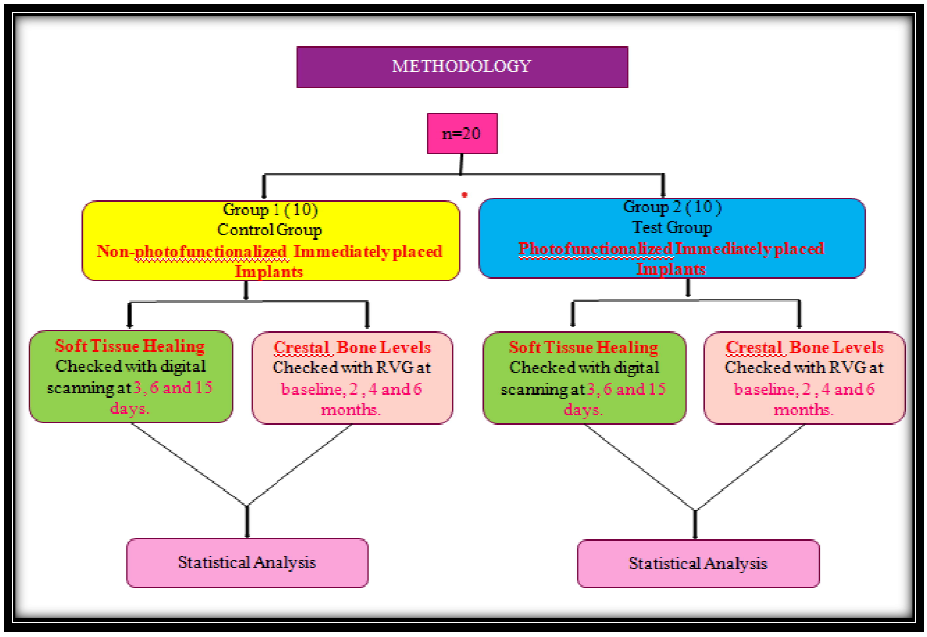

METHODOLOGY
n=20
Group 1 (10)
Control Group
Non-photofunctionalized Immediately placed Implants
Group 2 (10)
Test Group
Photofuncrionalized Immediately placed Implants
Soft Tissue Healing
Checked with digital scanning at 3, 6 and 15 days.
Crestal Bone Levels
Checked with RVG at baseline, 2 , 4 and 6 months.
Soft Tissue Healing
Checked with digital scanning at 3, 6 and 15 days.
Crestal Bone Levels
Checked with RVG at baseline, 2 , 4 and 6 months.
Statistical Analysis
Statistical Analysis

Fig:20-Sequential Steps In The Study Methodology

DIAGNOSTIC PROCEDURE:

The diagnostic procedure for this study involved a comprehensive pre-operative evaluation using clinical and radiographic methods. The aim was to gather detailed and accurate information to inform the treatment plan and ensure the success of the dental implants.

Initially, alongside this, diagnostic impressions were taken to create study casts of the maxillary and mandibular arches. These casts were fabricated using irreversible hydrocolloid (Prime) and poured with dental stone. The study casts provided an anatomical evaluation, allowing for the assessment of available bone volume, the shape of the alveolar bone, and the condition of the enclosing soft tissues. This information was critical for establishing the ideal location and

angulation of the implants.

Following this diagnostic radiographs were taken, including both orthopantomographs (OPG) and radiovisographs (RVG). The OPG images were used to evaluate bone density, the condition of the remaining dentition, and overall oral health. This radiographic tool was essential for identifying critical landmarks and assessing the gross anatomy of the jaws. It also helped detect any pathological conditions that might affect treatment planning and execution. The RVG served as a pivotal tool for evaluating the implant site, particularly for determining crestal bone remodeling post-implant placement. Using RIO view Ray IO software, the crestal bone height at the mesial and distal aspects of the implant site was measured. Standardization was ensured with the RINN XCP film holder and a custom-made bite index made from putty consistency. This bite index preserved imprints of opposing and adjacent teeth, ensuring consistent subsequent RVG captures and providing a reference for evaluating crestal bone remodelling at the implant site after three months.

Intraoral and extraoral digital photographs were taken using a CANON camera to document the condition of the soft tissues post-implant placement. These high-resolution images were essential for evaluating the healing process and planning the final prosthesis. The photographs served multiple purposes, including clinical evaluation, patient education, and crafting the final implant-supported prosthesis with accurate colour representation. Intraoral scanner was used to scan the implant sites to assess the size of wound with the help of 3D shape view software.

Before proceeding with the implant surgery, every patient was given a comprehensive verbal and written description about the treatment's risks and benefits. The potential advantages and disadvantages of implant therapy were discussed thoroughly to ensure that patients were well-

informed and could make an educated decision about their participation. Informed consent (Annexure V) was obtained from each participant, with a consent form duly signed and filed. This process adhered to the ethical standards set by the Institutional Ethical Committee of Santosh Dental College and Hospital (Ethical Approval No: SU/2023/2480[1]).

SURGICAL PROCEDURE

Stage 1

The triumph of dental implant procedures relies heavily on maintaining strict aseptic conditions, which were meticulously adhered to throughout the study. Patients were instructed to adhere to a specific regimen one week prior to surgery, which included consuming food and taking Augmentin 100mg antibiotics. Upon arrival, patients were seated on the dental chair and draped according to routine surgical protocols. Initial radiographic assessments were conducted using a RINN RVG sensor holder and addition silicone putty to register the bite index at the implant site for later reference. Prior to the commencement of surgery, patients were administered a chlorhexidine (0.2%) oral rinse, followed by skin preparation using povidone-iodine (5%) solution and draping. The administration of local anesthesia was done using 2% lignocaine with 1:80000 adrenaline. Extraction sites were evaluated before extraction. Atraumatic extraction of hopeless teeth was performed in both groups to maintain the integrity of the alveolar bone socket and the morphology of enclosing soft tissues, employing elevators and narrow beaked forceps. Flap reflection was minimized to conserve the vascular supply of the periosteum and minimize bone resorption. After extraction, the alveolar socket was meticulously debrided and assessed for structural integrity, and an implant slightly larger in diameter than the maximum width of the

tooth was selected. A guide drill was utilized to measure the socket length via radiovisiograph (RVG), and osteotomy preparation was performed with a length 2-3 mm greater than the socket length in both groups. Non-photofunctionalised immediate implant placement was conducted in **Group I** and photofunctionalised immediate implant placement was done in **Group II.** Selected implants were manually placed into the prepared site, followed by manual compression to achieve soft tissue secondary closure.

Intraoral photographs of the sites were captured using a DSLR 1500D camera and intraoral scanning was done to evaluate healing between both groups. Initial RVGs were obtained to assess crestal bone levels using customised bite index, with subsequent RVGs taken at 2, 4 and 6 months post-prosthetic loading to evaluate osseointegration and crestal bone levels. Postoperatively, patients were prescribed Augmentin 625mg twice daily, diclofenac sodium 50mg thrice daily, and chlorhexidine (0.2%) mouthwash two times daily for 5 days. Follow-up appointments were scheduled at the Department of Prosthodontics and Crown & Bridge, Santosh Dental College and Hospital on the 3^{rd} , 6^{th} and 15^{th} day for evaluation of soft tissue healing at the site.

Stage 2 Surgery

To evaluate crestal bone remodelling, patients were recalled 3 months later. Prior to the second stage surgery, patients were asked to perform intraoral rinsing with betadine mouthwash. Disinfection of the extraoral area was carried out using 7.5% Povidone-Iodine solution, while the oral cavity was made ready with 5% Povidone-Iodine solution. Local anaesthesia infiltration with lignocaine (1:80000 adrenaline) was administered. A mid-crestal incision was made at the

implant site along the crest of the edentulous ridge using a #15 surgical blade. Subsequently, a mucoperiosteal flap was elevated using a #9 Molts periosteal elevator with minimal exposure. The cover screw was removed from the implant, and an RVG was taken using a sensor holder with a customized bite index placed simultaneously in the patient's mouth, serving as a post-3month evaluation reference. Gingival formers were then placed intra-orally. After 14 days, the gingival formers were removed, and copings were placed to take an implant-level impression using addition silicone impression material. A jig trial was performed to verify the implant position, followed by the placement of implant-supported screw-retained single prostheses.

DATA COLLECTION

Soft tissue records were taken at day 0 and during follow-ups on the 3rd, 6th, and 15th days, while hard tissue parameters were evaluated at the day of loading (day 0), 2 months, 4 months and 6 months post-loading.

Soft tissue parameters

Implants were placed by the same operator so as to avoid bias. Peri-implant soft tissue assessment involved intraoral scanning with Shining 3D scanner. Wound size readings were recorded at specific intervals: Initial wound size on 1st day, and at 3rd, 6th, and 15th days post-operative.. The percentage of soft tissue healing was calculated on the basis of these measurements. This involved subtracting the wound size at each interval from the initial wound size, dividing the difference by the initial wound size, and multiplying by 100% to determine the percentage of wound healing.

Measurement Techniques

For accurate measurement of wound size, the STL (Stereo-Lithography, Standard Triangle Language, or Standard Tesselation Language) files were analysed in 3D Shape View software. The exact wound margins were marked by an operator who was not aware of the group allocation, so as to avoid operator bias blinding was done, and surface area was obtained in mm^2

Hard tissue parameters

Hard tissue parameters were evaluated at baseline, 2 months, 4 months and 6 months post-loading. Radiographic examinations were conducted using RVG and RINN X-ray holders to ensure standardized radiographs. These exams were done on the day of implant prosthesis loading and at 3 and 6 months later. The length of the radiopaque implant acted as a reference for measurements, with the implant neck and crest of alveolar bone used as points of reference. Digital measurements were taken at the mesial and distal aspects of each implant using RIO VIEW digital imaging software, with three measurements per implant. Mean values were then obtained to assess crestal bone loss.

Radiographic Standardization and Examination :

To ensure standardized radiographic images, we utilized the RINN XCP system for all Radio Visio Graphy (RVG) procedures. Radiographs were shot at four key intervals: on the day of prosthesis loading, and at 3, 4 and 6 months post-loading. This consistent protocol facilitated accurate and comparable assessments over time.

Calculation of Corrected Crestal Bone Level :

The evaluation of changes in crestal bone height involved calculating the corrected crestal bone level using a standardized formula. This correction accounted for any magnification or distortion inherent in the radiographic images.

Magnification Correction :

The actual implant length was divided by the measured implant length on the radiograph to determine the magnification ratio.

The formula for Corrected Crestal Bone Level:

The corrected crestal bone level was calculated using the formula:

$$\text{Corrected crestal bone level } (y') = \frac{\text{Actual implant length } (x)}{\text{Measured implant length } (x')} \times \text{Radiographic crestal bone level } (y)$$

The following figure (Figure 21) explains the above formula:

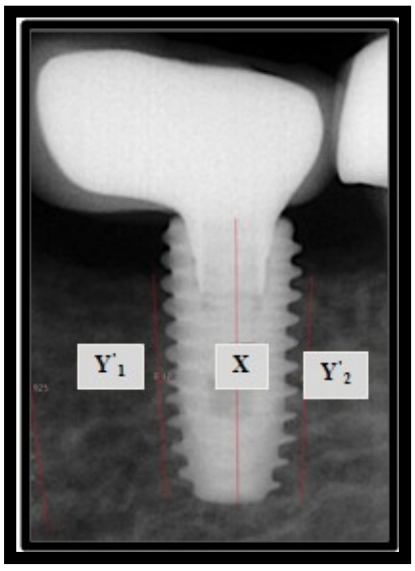


Fig: 21- Digramatic representation of crestal bone level

Digital Measurement :

Using RIO VIEW digital imaging software, we measured the distance from the alveolar crest to the implant apex at the mesial and distal aspects of every implant.

Recording and Averaging :

Two measurements were taken at the mesial and distal aspects of every implant to enhance reliability.

The average of these readings was estimated and used in the formula to assess the actual crestal bone level.

$$y' = \frac{y'_1 + y'_2}{2}$$

Assessment of Crestal Bone Level Changes

The primary focus of the hard tissue parameter evaluation was the assessment of crestal bone loss. By comparing the corrected crestal bone levels from the initial postoperative radiographs with those taken at the 3, 4 and 6-month follow-ups, we could effectively track changes in bone height over time.

REPRESENTATIVE CASE

A 46 year-old female presented at the Department of Prosthodontics with complaints of decayed teeth in the lower right and left posterior jaw region, seeking replacement options. The patient had no significant medical or dental history. Intraoral examination revealed missing teeth w.r.t.14 and 15, root stumps in w.r.t. 17, 27, 35, 36, 45 and 46 grossly decay w.r.t. 37. Treatment recommendations included implant placement at sites 35, 36 and 45, 46, along with fixed partial denture w.r.t. 13-16; 37.

The patient met the inclusion criteria and was selected as a case study sample. During the diagnostic phase, intraoral maximum intercuspation and arch photographs (Figures 22-33) were recorded, and diagnostic impressions were made and OPG was taken after explaining the study protocol and obtaining consent.

Fig: 22- Maximum Intercuspation Photograph

Fig: 23- Intra-oral Maxillary Arch

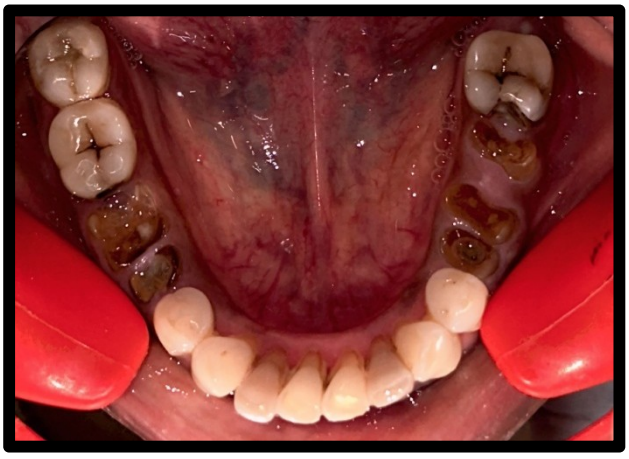


Fig: 24- Intra-oral Mandibular Arch

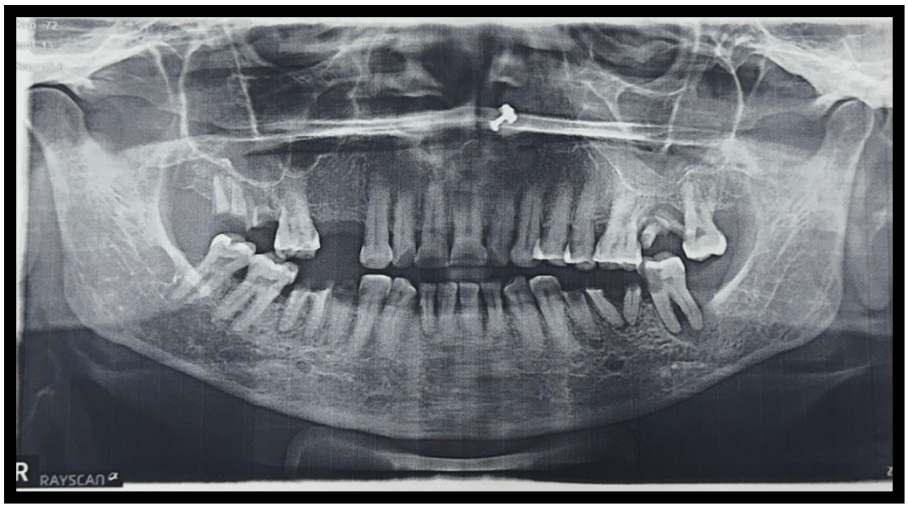


Fig: 25- Pre-operative OPG

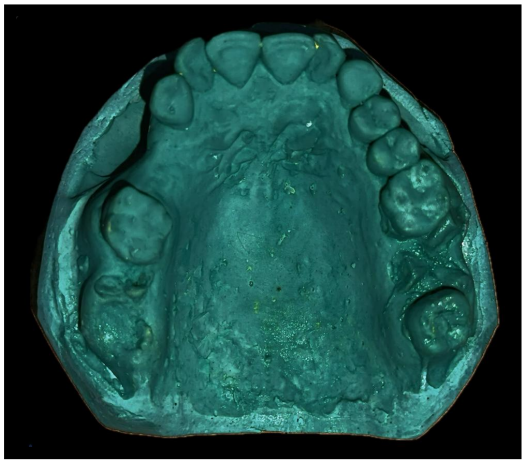


Fig: 26- Maxillary Diagnostic Cast

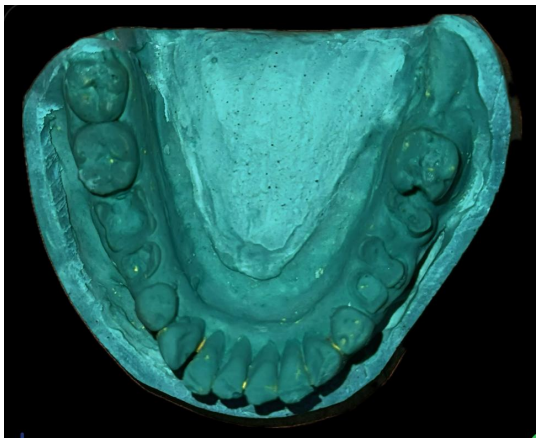


Fig: 27- Mandibular Diagnostic Cast

On the day of surgery, extractions were done w.r.t. 35, 36 and 45,46 (Figures 28, 29), followed by photofunctionalized immediate implant placement at sites 35,36 and non-photofunctionalized immediate implant placement at sites 45 and 46 (Figures 30). Assessment of primary stability assessment (79 ISQ Figure 33) was done for all the implants. Radiographic evaluation was conducted using intraoral RVG with RINN XCP holder for standardization (Figure 32, 34).

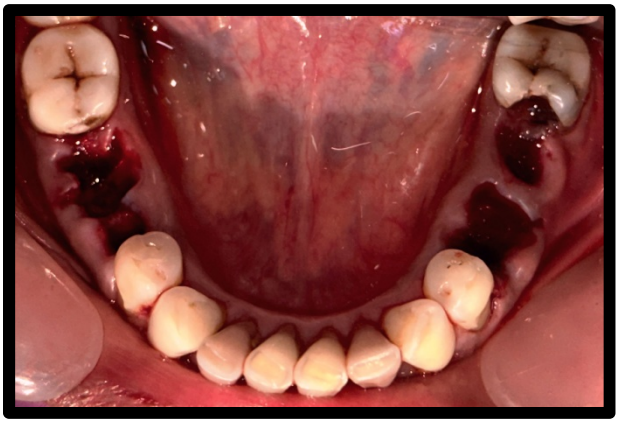


Fig: 28- Extraction w.r.t. 35,36,35,46

Fig: 29-Extracted Teeth

Fig: 30- Implant placement w.r.t. 35,36,45,46

Fig: 31-Post-operative OPG

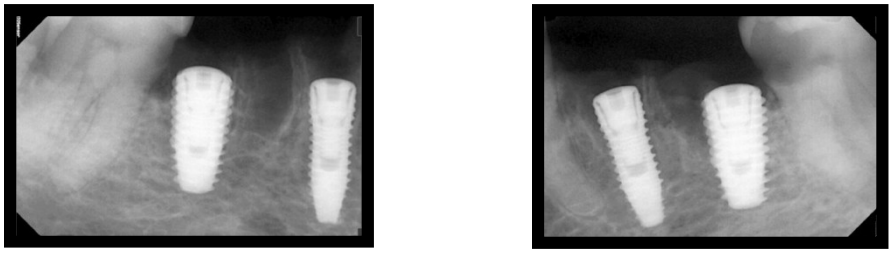


Fig: 32-Post-operative RVGs

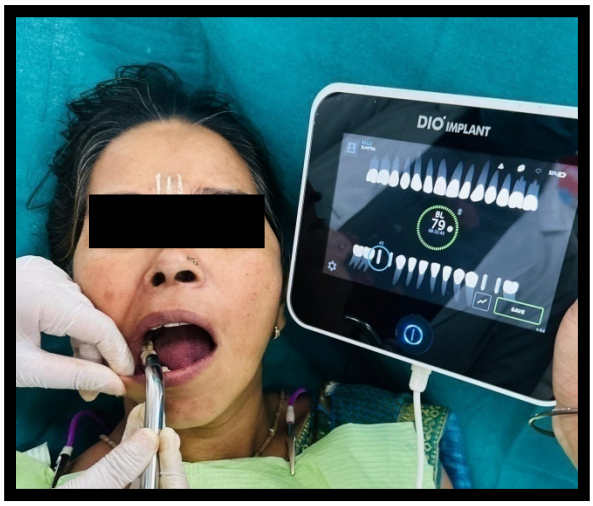


Fig: 33- Assessment of Implant Primary Stability using OSSTELL Device

Fig: 34- Use of RINN XCP for standardization of RVG

Intra-oral scanning was done at baseline (day 0), day 3 day 6 and 15 for evaluation of soft tissue healing for Group I (Figure 34-41) and Group II (Figure 42-49). The scans were assessed with the help of 3D shape view software, exact wound margins were marked and surface area was obtained in mm^2.

Group I (Non-Photofunctionalized)

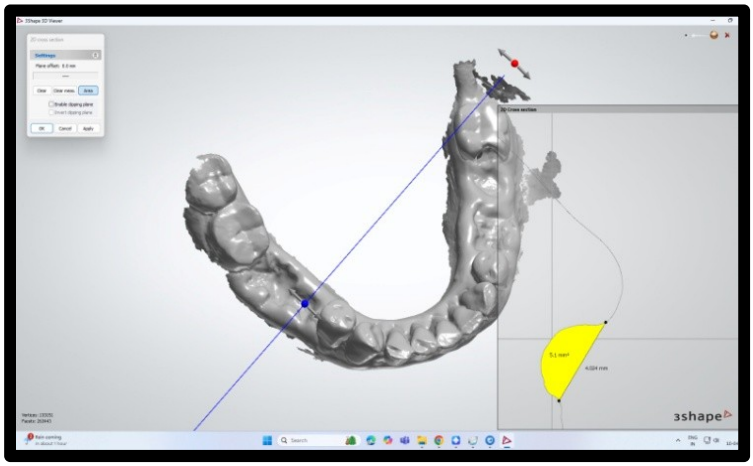


Fig: 35-Wound size evaluation for 45 at day 0

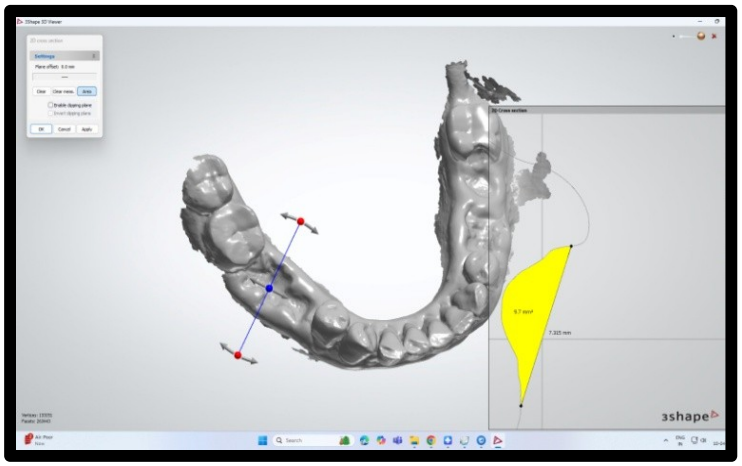


Fig: 36-Wound size evaluation for 46 at day 0

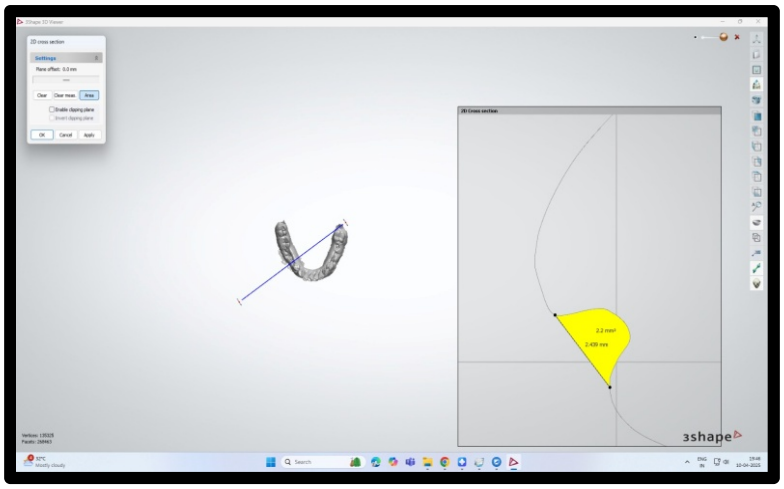


Fig: 37-Wound size evaluation for 45 at day 3

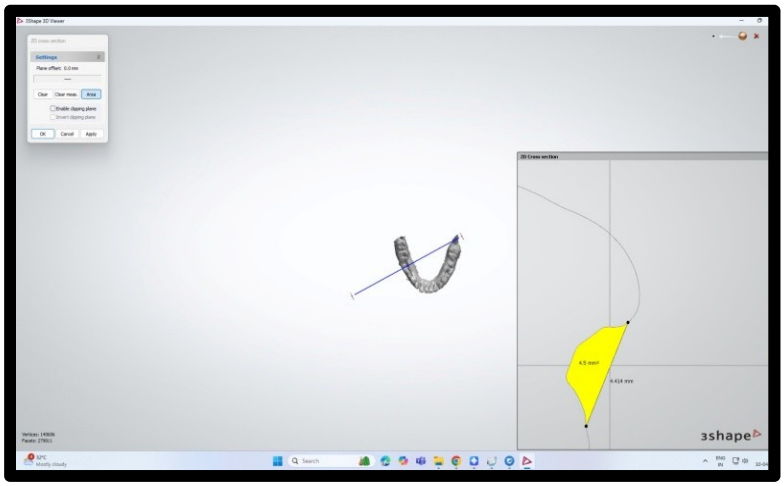


Fig: 38-Wound size evaluation for 46 at day 3

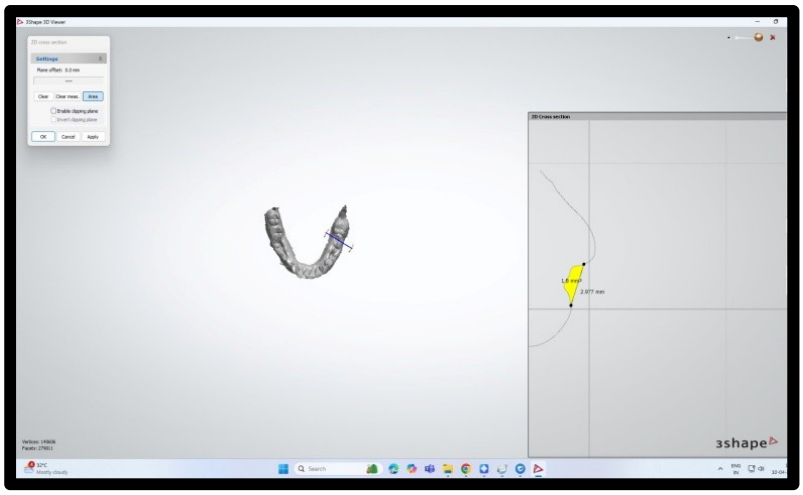


Fig: 39-Wound size evaluation for 45 at day 6

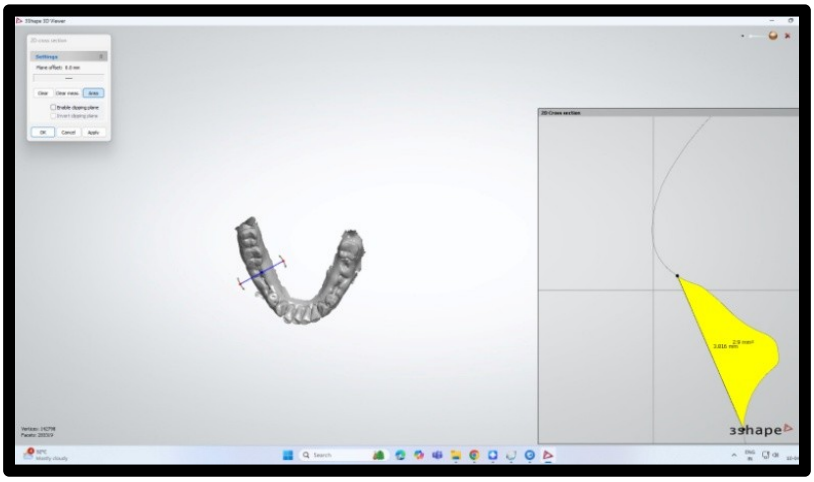


Fig: 40-Wound size evaluation for 46 at day 6

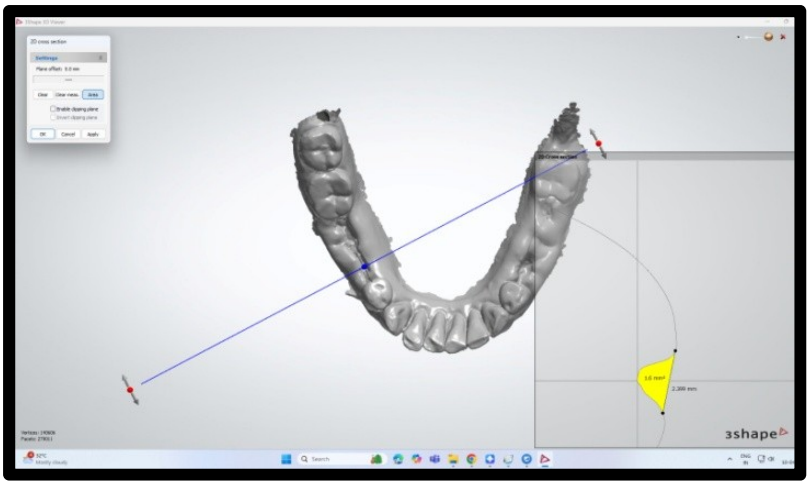


Fig: 41-Wound size evaluation for 45 at day 15

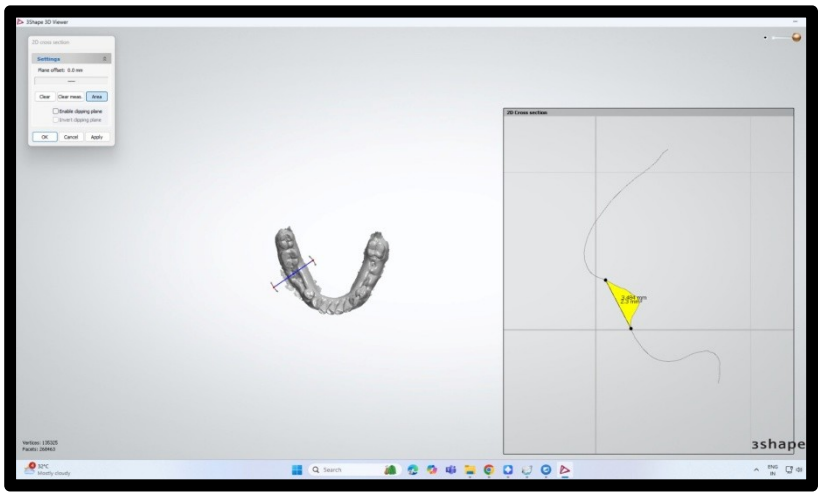


Fig: 42-Wound size evaluation for 46 at day 15

Group II (Photofunctionalized)

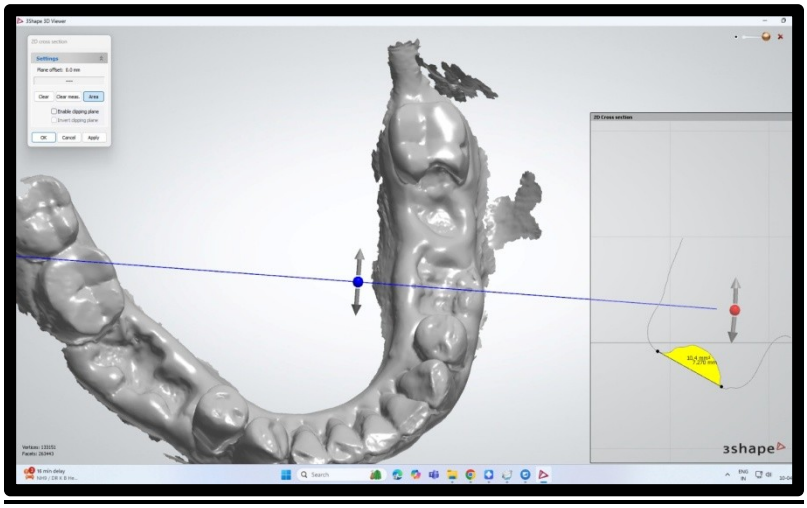


Fig: 43-Wound size evaluation for 35 at day 0

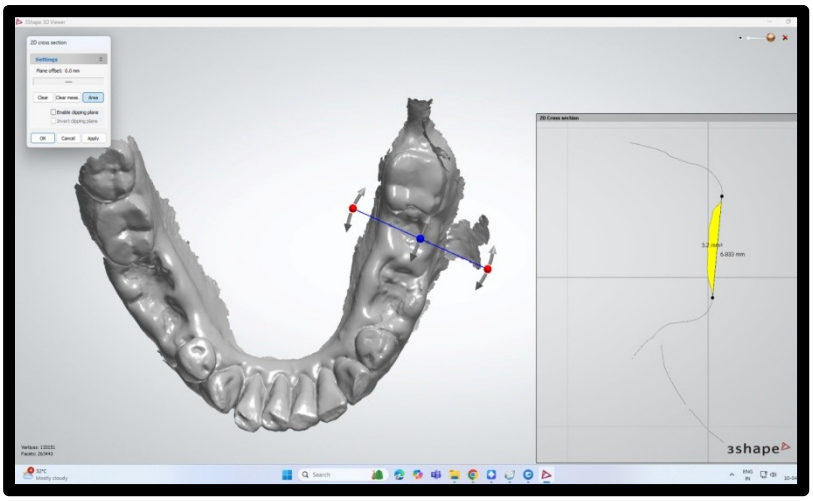


Fig: 44-Wound size evaluation for 36 at day 0

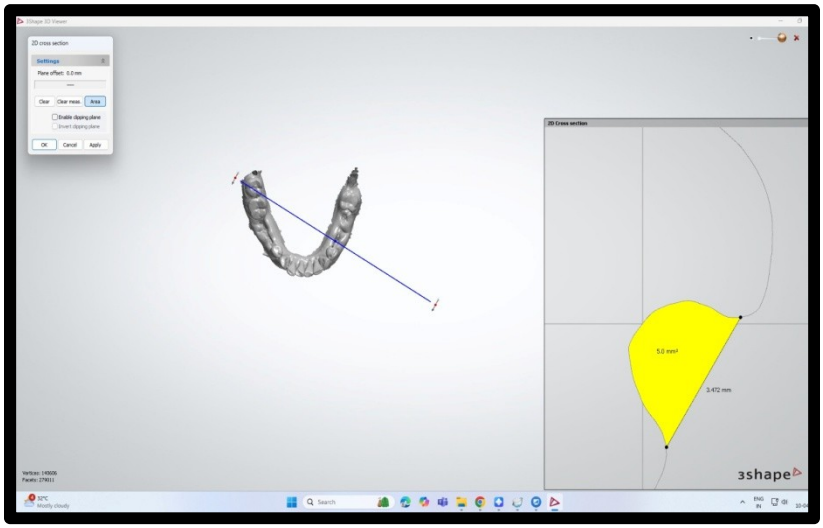


Fig: 45-Wound size evaluation for 35 at day 3

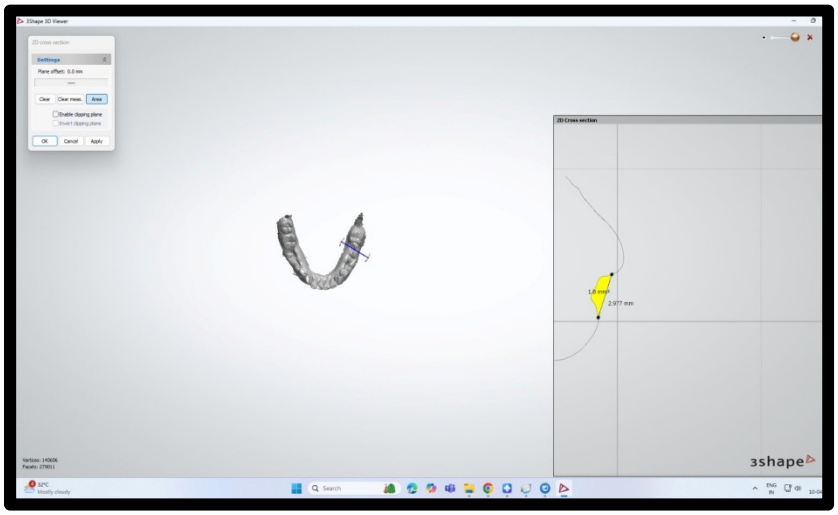


Fig: 46-Wound size evaluation for 36 at day 3

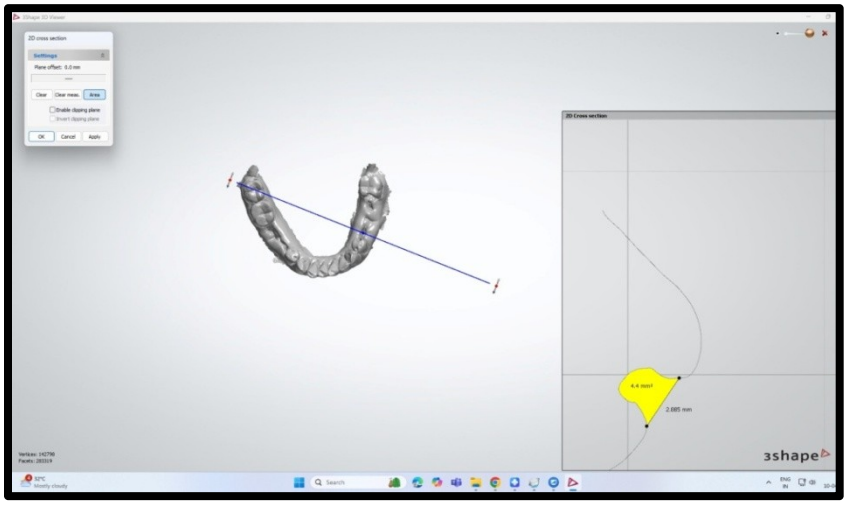


Fig: 47-Wound size evaluation for 35 at day 6

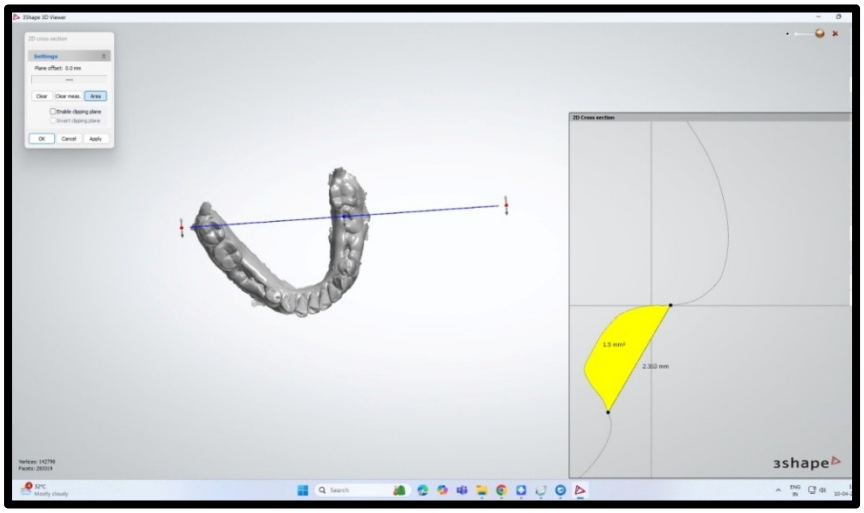


Fig: 48-Wound size evaluation for 36 at day 6

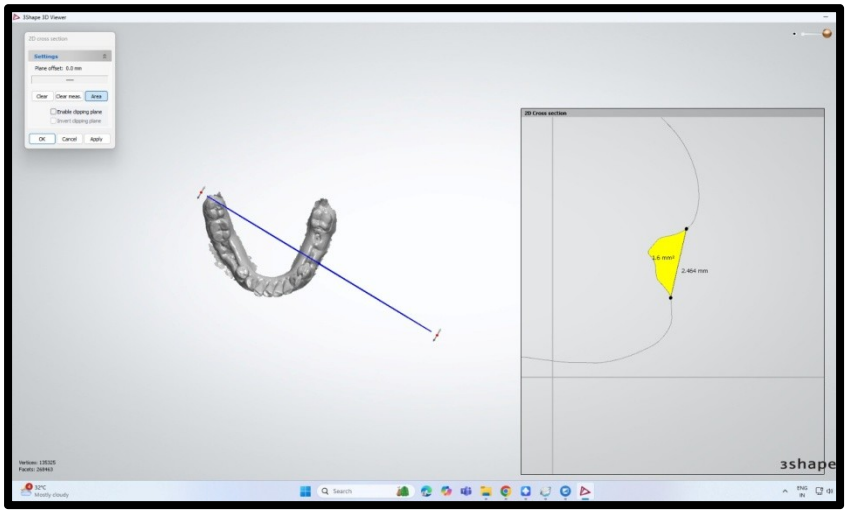


Fig: 49-Wound size evaluation for 35 at day 15

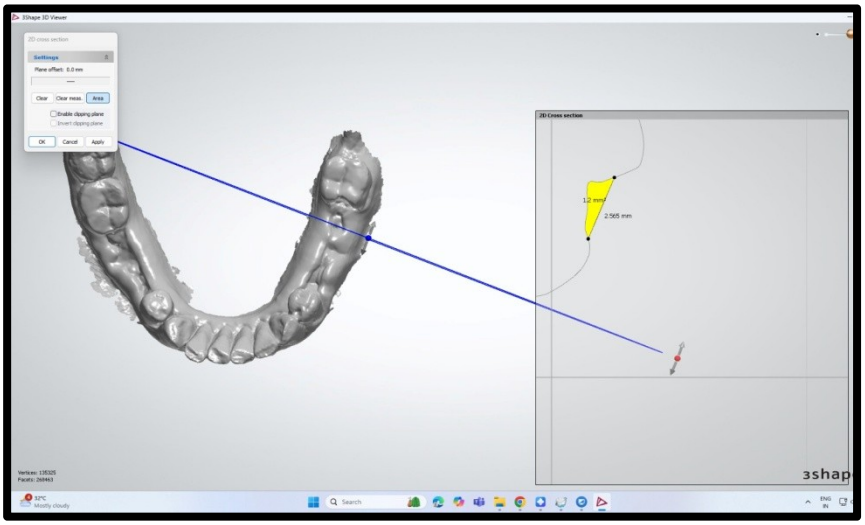


Fig: 50-Wound size evaluation for 36 at day 15

The patient returned for a second stage surgery after 3 months (Figures 50, 51), followed by implant-level impressions after 15 days (Figures 52, 53) and insertion of a screw-retained implant-supported prosthesis (Figures 54, 55).

Fig: 51- Second Stage Surgery

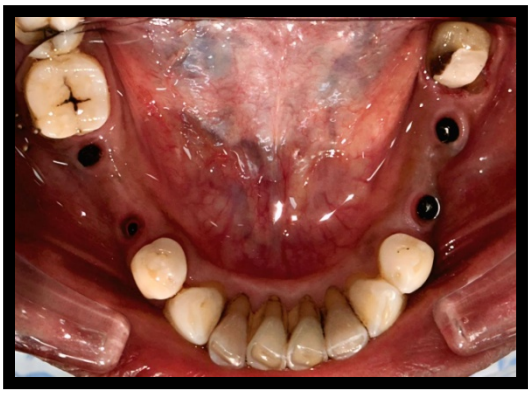


Fig: 52-Gingival collar formation

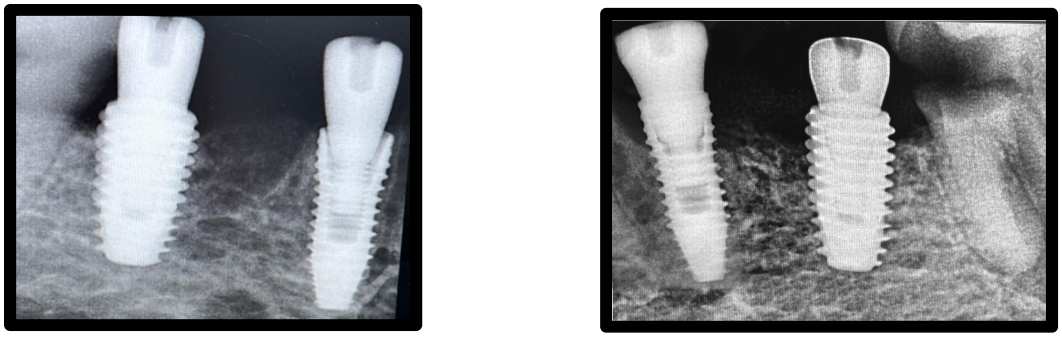
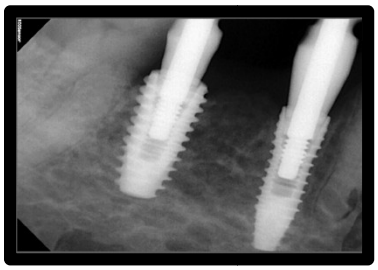


Fig: 53- RVG after Second Stage Surgery

Fig: 54-Placement of Closed Tray Copings

Fig: 55- Open Tray Impression

Fig: 56 (a)-Jig Trial Verfication



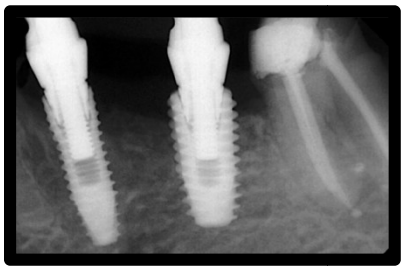


Fig: 56 (b)-RVGs of Jig Trial Verification

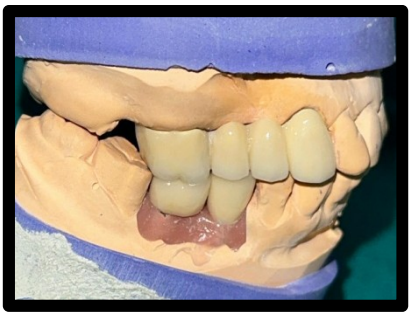


Fig: 57(a)-Right lateral

Fig: 57(b)-Frontal view

Fig: 57(c)-Left lateral

Fig: 57(d)-Maxillary Arch

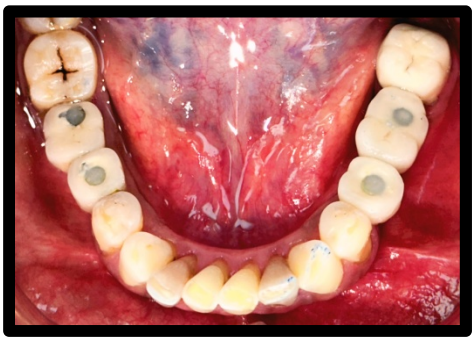


Fig: 57(e)-Mandibular Arch

Fig: 57(f)-Before

Fig: 57(g)-After

Fig: 57-FINAL PROSTHESIS CEMENTATION

Radiographic assessment of Crestal Bone Level changes at prosthesis insertion, 2, 4 and 6 months postoperatively was performed using radiovisiography.

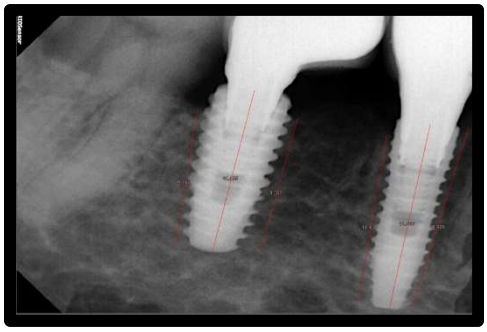


Fig: 58(a) - Baseline

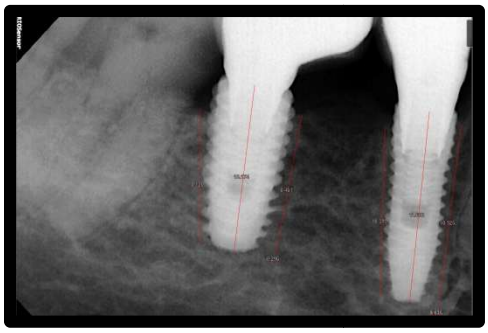


Fig: 58(b) - 2 months

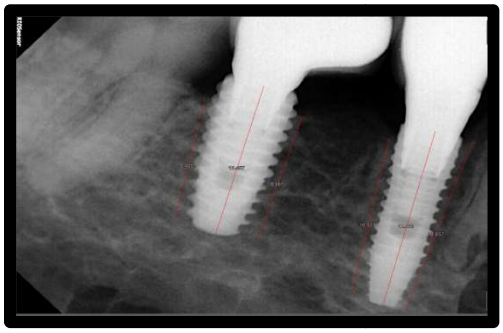


Fig: 58(c) - 4 months

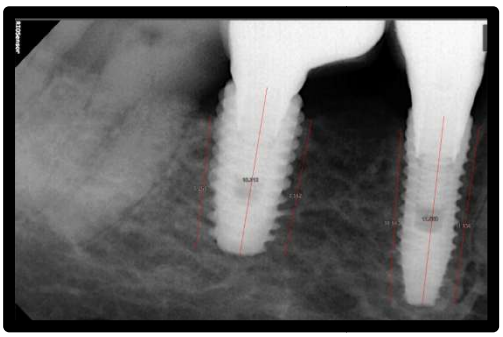


Fig: 58(d) - 6 months

Fig: 58-FOLLOW UP RADIOGRAPHS OF GROUP I (a) at baseline, (b) after 2 months, (c) after 4 months and (d after 6 months)

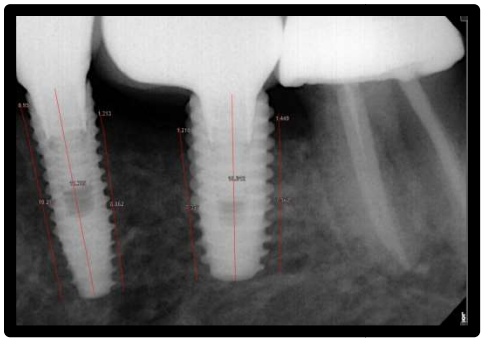


Fig: 59(a) - Baseline

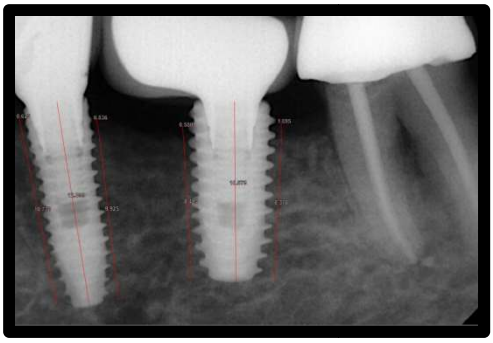


Fig: 59(b) - 2 months

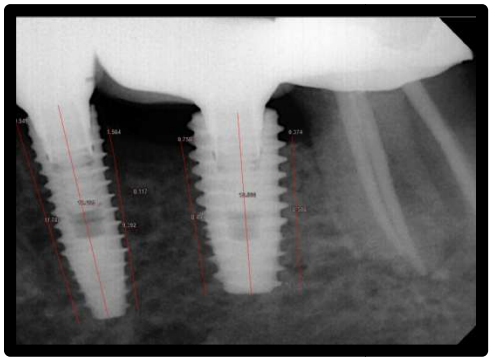


Fig: 59(c) - 4 months

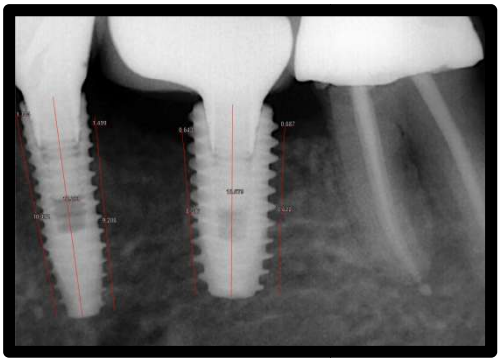


Fig: 59(d) - 6 months

Fig: 59-FOLLOW UP RADIOGRAPHS OF GROUP II (a) at baseline, (b) after 2 months, (c) after 4 months and (d after 6 months)

RESULTS

The clinical study was done in the Department of Prosthodontics and Crown & Bridge, Santosh Dental college and Hospital, to compare soft tissue healing and crestal bone levels between photofunctionalized and non-photofunctionalized implants. A total of 20 implants were placed in the split-mouth pattern. The implants were allocated in two groups i.e., Group 1 where non-photofunctionalized immediate implants (n=10) were placed and Group 2 where photofunctionalized immediate implants (n=10) were placed.

The SPSS statistical program, version 23.0, was used to evaluate the study data after it was imported into Microsoft Excel 2007. The mean, standard deviation, frequency, and percentage were among the descriptive statistics. For the current investigation, the level of significance was set at 5%.

The independent t tests were used for the comparison between groups. The data distribution was examined using the Shapiro-Wilk test, and the homogeneity of the variables was assessed using Levene's test.

For each group, Table 1 lists the wound size measurements for specific sites at day 1, day 3, day 6, and day 15. The average wound sizes at each interval are also provided. The data demonstrated the progression and reduction of wound sizes over the 15-day period for both groups, allowing for a comparative analysis of wound healing between the two treatment protocols.

Table 1: Distribution Of Wound Size (in mm2) At Different Intervals in Both Groups (Using 3D Shape View Software)

Group I Non-photofunctionalized immediate placement						**Group II** Photofunctionalized immediate implant placement					
Case	**Site**	**Day 0**	**Day 3**	**Day 6**	**Day 15**	**Case**	**Site**	**Day 0**	**Day 3**	**Day 6**	**Day 15**
1	**45**	5.1	2.2	1.8	1.6	**1**	**35**	10.4	5.0	4.4	1.6
2	**46**	9.7	4.5	2.9	2.3	**2**	**36**	3.2	1.8	1.5	1.2
3	**35**	9.5	2.3	1.1	0.8	**3**	**36**	12.4	2.1	1.8	1.7
4	**47**	15.1	6.6	6.0	2.7	**4**	**46**	7.8	6.4	1.3	0.6
5	**45**	3.5	3.4	2.9	2.0	**5**	**36**	5.2	4.6	3.8	1.1
6	**46**	4.8	4.2	3.4	2.8	**6**	**37**	16.2	14.3	12.2	3.2
7	**35**	6.4	4.7	4.2	3.1	**7**	**36**	10.2	6.2	3.1	1.2
8	**44**	10.2	9.8	8.0	4.3	**8**	**45**	12.9	12	10.2	3.2
9	**46**	6.5	4.7	4.2	3.3	**9**	**47**	14.2	6.0	5.6	1.6
10	**22**	4.6	4.2	3.8	2.1	**10**	**23**	5.3	4.6	3.8	2.1
Average		**7.54**	**4.66**	**3.83**	**1.75**	**Average**		**9.78**	**6.3**	**4.77**	**2.5**

In Table 2 progression of soft tissue healing, expressed as a percentage, at three different time intervals (Day 3, Day 6, and Day 15) within both Group I (non-photofunctionalized immediate implant placement) and Group II (photofunctionalized immediate implant placement). In Group I, the average soft tissue healing progression started at 32.478% on Day 3, increased to 43.852% on Day 6, and reached 61.612% by Day 15. The highest recorded healing percentage in Group 1 was 91.579% (Case 3, Day 15), while the lowest was 42.857% (Case 5, Day 15). In Group II, the soft tissue healing progression started at an average of 33.709% on Day 3, increased to 51.065% on Day 6, and peaked at 79.734% on Day 15. The highest healing percentage in Group II was 92.308% (Case 4, Day 15), and the lowest was 78.846% (Case 5, Day 15).

Table 2: Comparison of Soft Tissue Healing Progression (in%) at Different Time Intervals within each Group

Group I Non-photofunctionalized immediate placement						**Group II** Photofunctionalized immediate implant placement					
Case	**Site**	**Day 0**	**Day 3**	**Day 6**	**Day 15**	**Case**	**Site**	**Day 0**	**Day 3**	**Day 6**	**Day 15**
1	**45**	0	56.863	64.706	68.627	**1**	**35**	0	51.923	57.692	84.615
2	**46**	0	53.608	70.103	76.289	**2**	**36**	0	43.750	53.125	62.500
3	**35**	0	75.789	88.421	91.579	**3**	**36**	0	83.065	85.484	86.290
4	**47**	0	56.291	60.265	82.119	**4**	**46**	0	17.949	83.333	92.308
5	**45**	0	2.857	17.143	42.857	**5**	**36**	0	11.538	26.923	78.846
6	**46**	0	12.500	29.167	41.667	**6**	**37**	0	11.728	24.691	80.247
7	**35**	0	26.563	34.375	51.563	**7**	**36**	0	39.216	69.608	88.235
8	**44**	0	3.922	21.569	57.843	**8**	**45**	0	6.977	20.930	75.194
9	**46**	0	27.692	35.385	49.231	**9**	**47**	0	57.746	60.563	88.732
10	**22**	0	8.696	17.391	54.348	**10**	**23**	0	13.208	28.302	60.377
Average		**0**	**32.478**	**43.852**	**61.612**	**Average**		**0**	**33.709**	**51.065**	**79.734**

Table 3 illustrates the wound healing progression observed in Group 1, which underwent non-photofunctionalized immediate implant placement, started at 0% on Day 1 and reached an average healing percentage of 61.612% by Day 15. In contrast, Group 2, where photofunctionalized immediate implant placement was done, began at 0% on Day 1 and achieved an average healing percentage of 79.734% by Day 15. By Day 15, Group 2 demonstrated significantly advanced healing with an average healing percentage 1.03 times higher than Group 1 on Day 3, 1.16 times higher on Day 6, and 1.29 times higher on Day 15.

Table 3: Comparison Of Soft Tissue Healing (in%) at Different Intervals Between Both the Groups

Case	Day 0	Day 3		Day 6		Day 15	
	Group-1 v/s Group-2	Group I	Group II	Group I	Group II	Group I	Group II
1	0	56.863	51.923	64.706	57.692	68.627	84.615
2	0	53.608	43.750	70.103	53.125	76.289	62.500
3	0	75.789	83.065	88.421	85.484	91.579	86.290
4	0	56.291	17.949	60.265	83.333	82.119	92.308
5	0	2.857	11.538	17.143	26.923	42.857	78.846
6	0	12.500	11.728	29.167	24.691	41.667	80.247
7	0	26.563	39.216	34.375	69.608	51.563	88.235
8	0	3.922	6.977	21.569	20.930	57.843	75.194
9	0	27.692	57.746	35.385	60.563	49.231	88.732
10	0	8.696	13.208	17.391	28.302	54.348	60.377
Average	0	**32.478**	**33.709**	**43.852**	**51.065**	**61.612**	**79.734**

Table 4: Distribution Of Crestal Bone Level Changes (in mm) At Different Intervals in Both the Groups

Group I Non-photofunctionalized immediate placement					**Group II** Photofunctionalized immediate implant placement				
Case	**Baseline**	**2 months**	**4 months**	**6 months**	**Case**	**Baseline**	**2 months**	**4 months**	**6 months**
1	10.85	10.79	10.77	10.56	**1**	9.82	10.34	10.44	10.53
2	8.28	8.26	8.15	8.14	**2**	8.62	8.63	8.69	8.73
3	11.52	11.31	11.26	11.05	**3**	9.26	9.37	9.52	9.65
4	9.87	9.76	9.66	9.59	**4**	9.65	9.93	9.98	10.01
5	12.24	11.66	11.33	11.20	**5**	11.37	11.51	11.79	12.21
6	11.80	11.60	11.42	11.12	**6**	11.26	11.46	11.51	11.66
7	11.37	11.23	10.48	10.31	**7**	11.29	11.37	11.61	11.84
8	9.61	9.59	9.45	9.26	**8**	10.39	10.62	10.88	11.32
9	9.89	9.73	9.55	9.46	**9**	9.05	9.11	9.19	9.41
10	11.75	11.70	11.58	11.43	**10**	13.01	13.25	13.33	13.49
Average	10.718	10.563	10.365	10.212	**Average**	10.372	10.559	10.694	10.885

Table 4 lists the crestal bone levels at baseline, 2, 4 and 6 months for both the groups. The data showed a progressive gain in the bone levels post loading in Group II while a progressive loss in Group I.

OBSERVATIONS

The observations recorded (Table: 5) to evaluate the **wound size (in mm2)** in both groups were analysed using an Independent t-test, yielding the following results:

Table 5: Comparison Of Wound Size (in mm2) Between the Two Groups

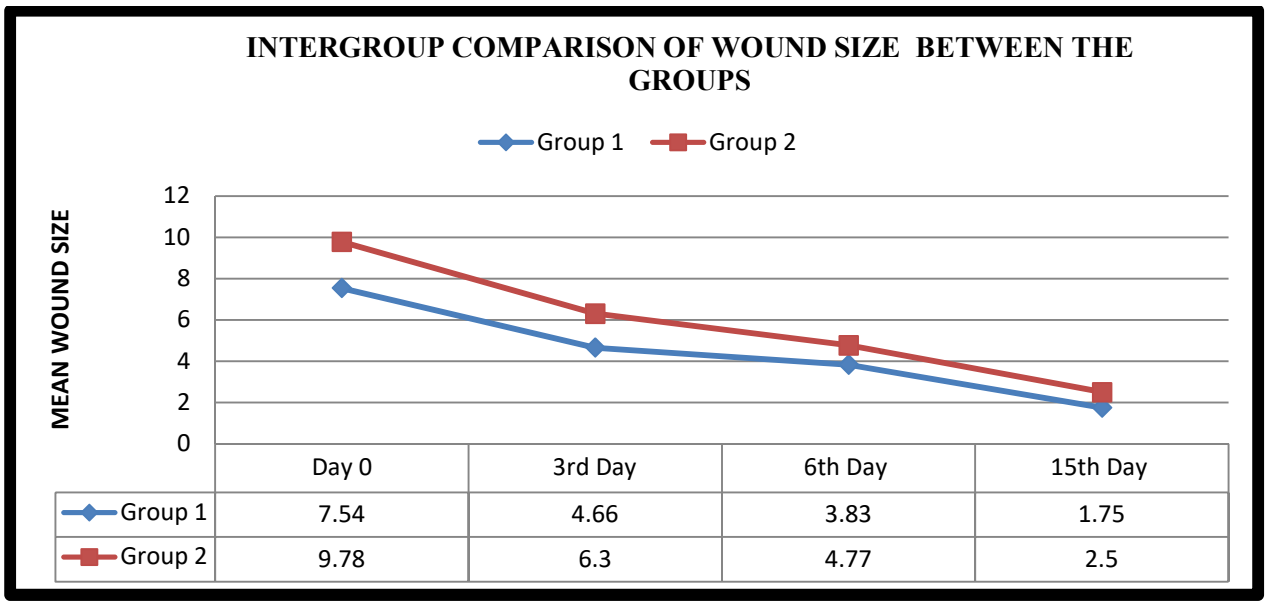
Interval	Group	N	Mean	SD	SE	Difference	p- value
Day 0	**Group 1**	10	7.540	3.551	1.123	0.235	0.221(Non-Sig)
	Group 2	10	9.780	4.296	1.358		
Day 3	**Group 1**	10	4.660	2.207	0.697	0.558	0.369(Non-Sig)
	Group 2	10	6.300	3.971	1.255		
Day 6	**Group 1**	10	3.830	1.996	0.631	0.532	0.477(Non-Sig)
	Group 2	10	4.770	3.677	1.163		
Day 15	**Group 1**	10	1.750	0.864	0.273	0.034	0.059(Non-Sig)
	Group 2	10	2.500	0.972	0.307		

Independent t test, Level of significance set at $p<0.05$

Table 5 compares the wound size (in mm2) between the two groups. The initial wound size of Group II was bigger than Group I and it remained so at all intervals. Overall, both groups demonstrated progressive wound healing over time, but this difference was not significant statistically.

Graph-1 compared the wound size (in mm²) between two groups over time, from the initial wound size measurement to the 15th day. The x-axis represents different time points: Initial wound (at the day of extraction), Day 3, Day 6, and Day 15, while the y-axis indicates the wound size in square millimetres. Group 1, represented by the blue line, starts with a wound size of around 7.54 mm² and shows a gradual decrease over time, reaching approximately 1.75 mm² by Day 15. Group 2, represented by the red line, begins with a slightly bigger wound size of around 9.78 mm² and also exhibits a consistent reduction, ending with a wound size just below 3 mm² by Day 15. Both groups show a similar pattern of wound healing, with Group 2 demonstrating a slightly faster reduction in wound size compared to Group 1.

Graph: 1- Comparison Of Wound Size (in mm2) Between Two Groups at Various Time Interval



	Day 0	3rd Day	6th Day	15th Day
Group 1	7.54	4.66	3.83	1.75
Group 2	9.78	6.3	4.77	2.5

The observations recorded (Table: 6) to evaluate the soft tissue healing progression (in %) in both groups were analysed using an Independent t-test, yielding the following results:

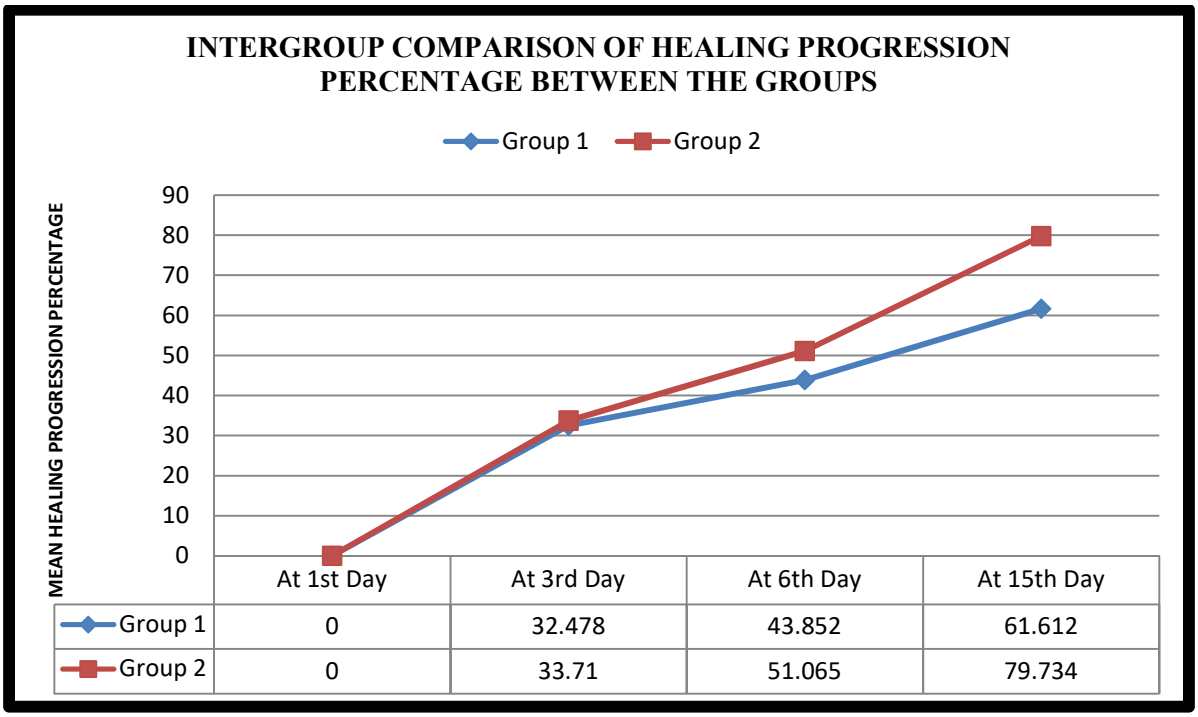
Table 6: Comparison Of Soft Tissue Healing (in %) Between Two Groups

Interval	Group	N	Mean	SD	SE	Difference	P value
Day 3	**Group 1**	10	32.478	26.245	8.299	0.248	0.816(Non-Sig)
	Group 2	10	33.710	25.461	8.051		
Day 6	**Group 1**	10	43.852	25.093	7.935	0.18	0.045(Sig)
	Group 2	10	51.065	24.523	7.755		
Day 15	**Group 1**	10	61.612	17.189	3.670	-1.98	0.001(Sig)
	Group 2	10	79.734	10.911	5.650		

Independent t test, Level of significance set at $p<0.05$

In evaluating the percentage of soft tissue healing between the two groups, significant differences were observed at various intervals. Group 1, with non-photofunctionalized immediate implant placement, showed an average wound healing progression from 0% at Day-1 to 32.478% on Day 3, 43.852% on Day 6, and 61.612% on Day 15. Group 2, with photofunctionalized immediate implant placement, demonstrated higher average healing rates, starting at 33.709% at Day 3 and increasing to 51.065% on Day 6, and 79.734% on Day 15.. These extreme values highlight the variability in individual healing responses. Overall, Group 2 consistently achieved superior soft tissue healing outcomes across all measured intervals, suggesting that delayed implant placement may facilitate better soft tissue healing (Graph 2).

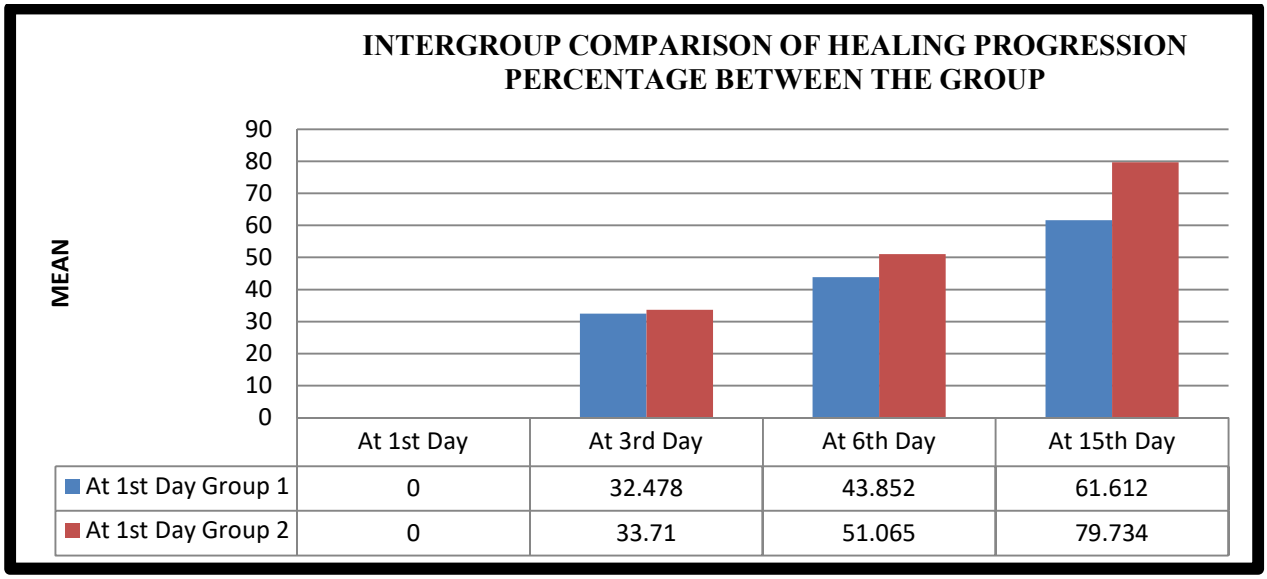
Graph: 2- Comparison Of Soft Tissue Healing (in %) Among Two Groups At Various Time Intervals



Graph 2 displays the percentage of soft tissue healing over time for two groups. The x-axis indicates the time intervals: Day 1, Day 3, Day 6, and Day 15. The y-axis represents the percentage of soft tissue healing, ranging from 0% to 90%.

On Day 1, both groups started with a low percentage of healing, close to 0%. By Day 3, Group 1 showed a moderate increase in healing to around 30%, while Group 2 showed a similar increase to approximately 30%. By Day 10, both groups continued to improve, with Group 1 reaching around 40% and Group 2 nearing 50%. On Day 15, Group 1 achieved about 60% healing, whereas Group 2 reached approximately 80%. This graph illustrates that Group 2 exhibits faster and greater soft tissue healing compared to Group 1 over the 15-day period.

Graph: 3- Comparison Of Soft Tissue Healing (in%) at Various Intervals Between Both the Groups



	At 1st Day	At 3rd Day	At 6th Day	At 15th Day
At 1st Day Group 1	0	32.478	43.852	61.612
At 1st Day Group 2	0	33.71	51.065	79.734

The bar graph illustrates the percentage of soft tissue healing for Group 1 (blue bars) and Group 2 (red bars) at four-time intervals: Day 1, Day 3, Day 6, and Day 15. On Day 1, both the groups show 0% healing . By Day 3, both the groups reached 30% healing. On Day 6, Group 1 showed 40% healing, and Group 2 progressed to 50%. By Day 15, Group 1 achieved 60% healing, and Group 2 reached approximately 800%.

Overall, Group 2 consistently exhibited a higher percentage of soft tissue healing compared to Group 1 at each time interval.

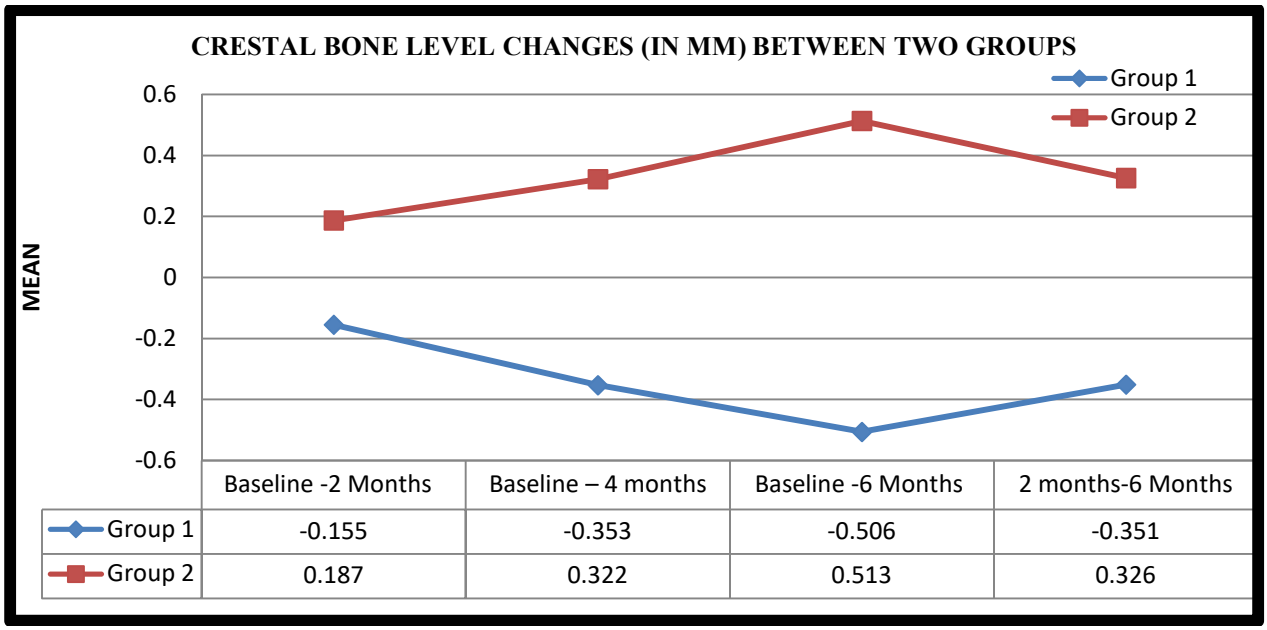
The observations recorded (Table:7) to evaluate crestal bone loss in both groups were analysed using an independent t-test, yielding the following results:

Table 7: Comparison Of Crestal Bone Level Changes (in mm) Between Two Groups

	GP	N	Mean	Std. Deviation	Std. Error Mean	P value
At 2nd Month	Group 1	10	-0.1550	0.164	0.052	0.001(Sig)
	Group 2	10	0.1870	0.145	0.046	
At 4nd Month	Group 1	10	-0.3530	0.302	0.095	0.001(Sig)
	Group 2	10	0.3220	0.160	0.050	
At 6th Month	Group 1	10	-0.5060	0.319	0.101	0.001(Sig)
	Group 2	10	0.5130	0.249	0.078	

Independent t test, Level of significance set at p<0.05

Graph: 4- Comparison Of Crestal Bone Level changes (in mm) Between Two Groups At Various Time Intervals.



Graph 4 compares crestal bone level changes between two groups over four time periods: Baseline, 2 months, 4 months and 6 months. From Baseline to 3 months, Group 1 showed crestal bone loss which started at about 0.155mm while Group 2 showed bone gain that began at 0.187mm. In subsequent intervals Group 1 continued to exhibit bone loss dropping to 0.506 after 6 months whereas Group 2 showed a consistent increase in crestal bone levels upto 0.513 after 6 months.

Group 2 showed crestal bone gain as compared to Group 1 which underwent crestal bone loss.

The study results indicate that Group 2 showed better outcomes in terms of soft tissue healing and crestal bone maintenance compared to Group 1. Graph 1 illustrates a noticeable reduction in wound size over 15 days for both groups, with Group 2 demonstrating a slightly faster decline, indicating accelerated healing (Graph 2).

Furthermore, the table comparing crestal bone loss demonstrated consistent increase in crestal bone levels in Group 2 across all study intervals, particularly from Baseline to 6 months. Overall, these findings suggest that the treatment protocol for Group 2 may be more effective in enhancing oral health and stability following implant placement.

DISCUSSION

Nowadays, dental implants are frequently being placed in clinical settings for the replacement of lost teeth, offering patients greater comfort and improved function compared to conventional prostheses[29]. Successful dental implant treatment requires maintaining implant health over the long term to ensure continued prosthetic function (Ammann P et al., 2003) [30]. Several factors influence the successful integration of endosseous implants, including the maintenance of BIC and the biological response of the soft tissue at the transmucosal zone. These outcomes can be affected by the patient's overall health, implant surface properties, surgical technique, and the type of bone at the implant site (Turkyilmaz I et al., 2007, 2008) [30].

Ultraviolet (UV) photofunctionalization has evolved as an innovative method that significantly alters the surface properties of titanium implants. When titanium surfaces are exposed to UV light immediately before implantation, they undergo substantial physicochemical modifications that enhance their interaction with the surrounding biological environment. These changes lead to improved cellular behaviors—including attachment, spreading, adhesion, proliferation, differentiation, and mineralization, which accelerates and enhances the quality of osseointegration, ultimately improving clinical outcomes [2].

A split-mouth study was designed, in which on one side non-photofunctionalized immediate implant were placed, while on the other side photofunctionalized immediate implant placement was done. This design was chosen to eliminate inter-subject variability and allow direct comparison within the same patient, thereby providing more accurate and reliable results. Also blinding of the data analyst was done to further ensure unbiased and reliable results. This eliminated observer bias in interpreting radiographic and clinical data. Blinding strengthens the

validity of comparative analyses, particularly in split-mouth studies, by ensuring objective assessment of UV photofunctionalization's effects on soft tissue sealing and bone preservation.

Standard immediate implant placement procedures involve sutures to secure the surgical site, which is an established practice. However, tissue tension from tight sutures can sometimes affect blood supply and healing, and some patients may experience reactions to suture materials, including inflammation or infection so primary closure was not done to avoid the aforementioned consequences. Another important criteria for the success of implant is the preservation of crestal bone levels surrounding the implants. Therefore, this investigation was necessary to assess how PhF affected the crestal bone levels and soft tissue healing surrounding implants, which could reduce patient discomfort and injury while improving clinical results.

The seal created by soft tissue, often known as soft tissue integration, is the process by which the underlying connective tissue and epithelium of the surrounding mucosa of implant adhere to the transmucosal area of dental implants [31,32]. The soft tissue seal is a comparatively delicate barrier of soft tissue that aids in securing the implant-gingiva junction and isolating the osseointegrated implant component from the heavily contaminated oral cavity, in contrast to osseointegration, which describes a solid and compact 2 part aattachment between the implant and bone [33]. Bacteria from the oral cavity may infiltrate the interface once the soft tissue seal is broken, resulting in peri-implant mucositis and peri-implantitis, which can cause irreparable marginal bone loss [34], thereby, jeopardizing the viability of dental implants [35].

The entire dynamic peri-implant healing process affects the possibility of creating a strong soft tissue seal around implants. In particular, the sequence of host immunological reactions that coincide with implant transmucosal area implantation can be characterized as follows [36]: (1)

coagulation and bleeding; (2) acute inflammatory response, which primarily consists of removing pathogenic microbes and removing broken tissue; (3) reduced inflammatory duration, which consists of a changed immune cell and cytokine composition, preparing for the next stage of soft tissue regeneration; (4) granulation tissue stage, which is characterized by the proliferation of soft tissue cells and vascularization; (5) the ECM remodeling stage, which culminates in the creation of a soft tissue seal by causing collagen fibers to become thick and ordered as cell proliferation slows.

Enhancing the transmucosal region's ability to adhere to the peri-implant mucosa is crucial. Specifically, the increased bonding ability can be achieved by either promotion of collagen's perpendicular integration to the surface of the transmucosal area or encouraging cell adhesion (primarily the fibroblasts and epithelial cells) with heightened focal adhesion development and hemidesmosomes. Surface energy, chemistry, and topography are the variables that affect the surface of the transmucosal region. The solid-liquid contact angle measures the final attribute, which is represented in surface wettability [(37)].

One innovative method that causes a change in the properties of titanium implant surface is UV photofunctionalization. By exposing titanium surfaces to radiation right before usage, photofunctionalization causes a number of significant physicochemical alterations that significantly affect how the implants engage with their biological surroundings. The speed and quality of osseointegration and the ensuing clinical results are subsequently improved by these modifications, which also enhance cellular reactions such as attachment, spread, adhesion, proliferation, differentiation, and mineralization [(2)]. Increased oral connective tissue attachment strength and retention, also mucosal fibroblast adherence, are linked to UV photofunctionalized titanium surfaces, creating a robust gingival seal around the prosthetic parts or implant neck

[38,39]. Without changing the surface roughness or other morphological characteristics, It has been proposed that UV photofunctionalization serves as an efficient pre treatment to significantly increase the Ti's surface hydrophilicity [40,41]. Consequently, the high wettability performance following UV treatment led to increased production of proteins related to hemidesmosomes in epithelium and focal adhesions in fibroblasts [42-44], thereby, contributing to a better soft tissue healing around implants.

Standard procedure for immediate implantation involves the filling of bone graft to reduce the jumping distance, and membranes are used to secure them. Omitting graft materials simplifies the surgical procedure and reduces potential complications related to graft integration, such as infection or rejection.

Considering these challenges, a pilot study was conducted where photofunctionalized implants were placed on one side of the arch while non-photofunctionalized implants were placed on the other side. Primary closure was not done in both the cases. Soft tissue records were taken using intraoral scanning at day 0, 3rd, 6th and 15th days, the image data was saved as STL files which was further analysed with the help of 3D shape view software. Intraoral scanning provides precise margins and allows for real-time visualization of the peri-implant soft tissue which further contributes to better accuracy of results [45,46].

In the assessment of this pilot study, we found that the soft tissue healing was better at the site where photofunctionalized implants were placed. Based on these promising results, the study was conducted to further investigate and validate these findings.

In analysing the results, our study found significant differences in soft tissue healing progression between Group I (non-photofunctionalized immediate implant placement) and Group II

(photofunctionalized immediate implant placement). In Group I, soft tissue healing progression at day 1 started at 0%, indicating no initial healing. By the 3rd day, healing had progressed to 32.478%, further improving to 43.852% by the 6th day, and reaching 61.612% by the 15th day. In contrast, Group II exhibited a different healing pattern. Like Group I, the soft tissue healing progression at day 1 started at 0%. However, by the 3rd day, healing rapidly progressed to 33.709%. By the 6th day, healing had significantly improved to 51.065%, and by the 15th day, it reached an impressive 79.734%.

Comparative analysis of the two groups revealed the following: by the 3rd day, Group II's soft tissue healing was 33.709% compared to Group I's 32.478%, making Group II's healing 1.03 times greater. By the 6th day, Group II's healing was 51.065% compared to Group I's 43.852%, making Group II's healing 1.16 times greater. By the 15th day, Group II's healing was 79.734% compared to Group I's 61.612%, making Group II's healing 1.29 times greater.

These findings highlighted a consistent trend where Group II exhibited superior soft tissue healing at each observed interval. The progression in Group II was markedly faster and more effective, indicating that photofunctionalization increases the rate of soft tissue healing around immediate implants.

Research by de Avila et al. [47] showed that photofunctionalization, or ultraviolet (UV) treatment of titanium immediately before clinical application, modulates the interaction of the implant surface with human polymicrobial oral biofilm in environments containing salivary and blood components. This surface modification induces a transition from a hydrophobic to a superhydrophilic state. UV-treated titanium surfaces demonstrate a remarkable lowering of initial bacterial adhesion and subsequent biofilm development when compared to untreated

surfaces, additionally, it can also suppress the expression of proinflammatory gene IL-1β [48], thereby favoring peri-implant soft tissue healing, which are in line with our study's conclusions.

Another study by Nakhaei et al. [49] demonstrated that ultraviolet (UV) treatment significantly influences the conduct oral epithelial cells of humans grown on titanium surfaces, resulting in increased cell attachment and enhanced cellular spreading. This improved initial attachment is attributed, in part, to an electrostatic mechanism induced by UV irradiation [50], which triggers a photocatalytic reaction on the titanium surface, this reaction imparts a positive surface charge to the titanium, thereby attracting negatively charged proteins and cells, facilitating cell adhesion [51,41]. The electrostatic nature of this interaction is further supported by observations that UV-mediated cellular attachment can be attenuated when the surface charge is neutralized or masked by monovalent anions [41].

Epithelial cell attachment to biomaterial surfaces primarily occurs through hemidesmosomes within adhesion plaques [52,53]. Strengthening this interaction is critical for achieving effective soft tissue integration. UV-treated titanium surfaces have been shown to upregulate key hemidesmosome-related genes, including *integrin β4* and *laminin-5*. This upregulation is likely responsible for the increased epithelial cell retention observed on UV-modified surfaces, even under enzymatic and mechanical challenges. Additionally, the observed enhancement in cellular spreading may further modulate adhesion strength and influence downstream processes such as proliferation and cellular function. Since epithelial cells are anchorage-dependent, increased spreading may be pivotal in supporting their biological activity and integration on implant surfaces [54,55].

Moreover, Ikeda et al. [56] concluded that ultraviolet (UV) treatment induces superhydrophilicity and facilitates the demolition of hydrocarbon contaminants from the titanium surface. Clinically, this surface modification method has significant potential for enhancing soft tissue healing by promoting a more effective connective tissue seal, thereby reducing the risk of bacterial infiltration in the peri-implant environment. Furthermore, the first biological component is blood which interact with the titanium surface, initiating a series of cellular and molecular incidents at the bone–implant articulation. Areid et al.[57] demonstrated that UV-irradiated titanium surfaces, which exhibit enhanced hydrophilicity, can accelerate blood coagulation and promote wound healing as well as tissue integration. By increasing surface wettability, the area of contact between the titanium and body fluids is enhanced, thereby facilitating improved protein adsorption and cellular attachment, which are essential for successful osseointegration [58].

Branemark stated that, successful osseointegration is contingent upon the rapid healing of the peri-implant mucosa in the marginal area, which serves to establish a protective seal over the underlying supporting structures [59]. The biological response and behavior of peri-implant soft tissues are crucial for the overall success and longevity of dental implants [60]. Thus, photofunctionalization of titanium represents an emerging surface modification strategy aimed at enhancing soft tissue integration with implant devices. This approach contributes to the prevention of exogenous microbial contamination and supports the durability of the implant.

The status of peri-implant soft tissues has been identified as a contributing reason of marginal bone resorption surrounding dental implants [61]. By promoting faster soft tissue healing and reducing inflammation, photofunctionalization helps to stabilize the soft tissue and create a more favorable environment for bone preservation. This stabilization is crucial for maintaining crestal bone levels, as excessive inflammation and poor soft tissue healing are often associated with

bone resorption around implants. Thus, this technique not only accelerates soft tissue healing but also contributes to better crestal bone level maintenance, enhancing the overall success and longevity of dental implants.

Marginal bone loss (MBL) is regarded as a sensitive and reliable parameter for assessing implant success, as pathological bone resorption may compromise osseointegration and ultimately lead to implant failure [(62)]. Koller et al.[(63)] states that although precise etiology of marginal bone loss remains unclear, several contributing factors have been identified, including surgical trauma, bacterial contamination, biomechanical overload, and the occurrence of a microgap at the implant–abutment junction, all of which are said to play a significant part in crestal bone resorption.

Evaluation of crestal bone levels was done by taking standardized intraoral radiographs with RINN XCP (Extension Cone Paralleling) device. By employing the paralleling technique, the RINN system ensures that the X-ray beam is perpendicular to the film or digital sensor and parallel to the implant's long axis, minimizing geometric distortion and providing clear visualization of crestal bone margins. This precision, as supported by Duckworth et al. [(64)] is essential for accurately measuring marginal bone loss (MBL), with studies indicating that standardized radiographs can achieve measurement accuracy within 0.1-0.2 mm, crucial for detecting early bone resorption that could compromise implant stability. The RINN device's color-coded biteblocks and aiming rings ensure consistent receptor positioning across follow-up visits, enabling reproducible images to track crestal bone changes over time, as emphasized by Whaites and Drage [(65)]. Additionally, the RINN system's rectangular collimation reduces radiation exposure to surrounding tissues, protecting bone and soft tissue health, while its compatibility with digital sensors supports high-resolution imaging for precise bone level

assessment. By minimizing patient discomfort and soft tissue trauma through ergonomic biteblocks, the RINN device facilitates imaging without disturbing the peri-implant environment, indirectly supporting bone preservation by reducing inflammation risks.

Excessive crestal bone loss may cause implant instability and failure making it essential to monitor these changes closely. Our study found that photofunctionalized implants not only minimized MBL but also promoted bone gain, with mean crestal bone gains of 0.187 mm, 0.322 mm, and 0.513 mm at 2, 4, and 6 months post-loading, respectively, compared to mean losses of 0.155 mm, 0.353 mm, and 0.506 mm in non-photofunctionalized implants.

These outcomes are consistent with Funato and Ogawa's [19] findings which reported bone gain in photofunctionalized implants after placement in fresh extraction sockets. They attributed it to the improved osteoconductive properties of photofunctionalized implants which facilitates not only improved osseointegration along the implant body and apex region but also promote osteomorphogenesis in the peri-implant cervical area. Photofunctionalized implants have been shown to initiate osteogenesis directly at the implant surface, with bone formation rapidly progressing outward to integrate with the surrounding host bone. This process, known as contact osteogenesis, results in the establishment of a stronger and continuous bone seal around the implant [66].

Ohyama et al. [67] demonstrated that a BIC of up to 98.2%, achievable through photofunctionalization, enhances peri-implant stress distribution and diffusion. This improved biomechanical environment may offer a potential strategy for mitigating stress-induced crestal bone loss around implants. Furthermore, Aita et al. [50] found that the in vivo strength of osseointegration achieved with photofunctionalized implants is approximately three times greater

than that observed with non-treated implants. Additionally, soft tissue interposition at the bone–implant boundary is markedly reduced, with a reported incidence of less than 1% for photofunctionalized implants, in comparison to over 20% for non-photofunctionalised counterparts. Owing to this near-complete suppression of soft tissue interference and a BIC approaching 100%, the resulting peri-implant bone formation has been termed 'super osseointegration'—a designation wherein the prefix 'super' denotes minimal resistance, reflecting the exceptional biological compatibility and integration efficiency of the photofunctionalized implant surface [68,69,43,70,71]. Photofunctionalization enhances bone-implant integration, achieving both greater strength and increased stability [72] . All these findings support the maintenance and subsequent gain in the crestal bone levels following photofunctionalization.

Elsubeihi and Heersche [73] & Covani et al. [74] suggested that bacterial infection is the most likely cause of implant failure and crestal bone loss at the implant neck. Alternatively, the observed marginal bone reduction and peri-implant inflammation may also be attributed to incomplete bone remodeling processes persisting three months post-extraction. Ishijima et al. [75] reported that When titanium surfaces are exposed to UV light, human oral bacteria attach less readily and form biofilms, thereby reducing the chance of peri-implantitis and its associated crestal bone loss. As reported by Schropp and Wenzel [76] alveolar bone resorption and remodeling are unavoidable consequences of tooth extraction and are further influenced by dental implant placement and functional loading. But the degree of bone loss exhibits variability across cases.

Peri-implantitis is a pathological condition that can cause progressive bone loss around implant and may ultimately lead to implant failure [77]. Adell et al. [78] found that during healing and the

first year following loading, there was a mean marginal bone loss of 1.2 mm from the first thread.

Alberktson et al. [79] suggested that in the first year after implantation, there should be minimal bone level alterations of less than 1 to 1.5 mm, with less than 0.2 mm loss of bone per year. Some researchers propose that the essential bone loss values one year after implantation should be lower than 1.5 mm, and after that, the mean yearly loss should be 0.1 mm [80,81]. Lately, it has been proposed that in the first year, a dental implant is deemed unsuccessful should it be lost, movable, or exhibits peri-implant bone loss of more than 1.0 mm and more than 0.2 mm. annually thereafter [82]. In our study, the measured mean crestal bone levels changes were below these critical values for non-photofunctunalized implants and there was a gain in the crestal bone levels in photofunctunalized implants, indicating success.

The study results are in support with the finding that UV photofunctionalization represents a paradigm shift in implantology by increasing soft tissue healing and crestal bone stability without altering surface topography. Its ability to create a pellicle-free, superhydrophilic, positively charged surface promotes osteogenic cell interactions, inhibits bacterial adhesion, and supports robust soft tissue sealing. These attributes reduce inflammation, minimize MBL, and promote bone gain, particularly in challenging scenarios like immediate implant placement. By optimizing osseointegration, improving soft tissue responses, and enhancing bacterial resistance, UV photofunctionalization sets a new standard for dental implant performance, promising improved long-term clinical outcomes.

LIMITATIONS

This study, while providing insightful knowledge into the comparative effectiveness of photofunctionalized and non- photofunctionalized implant placement, has several limitations that must be considered. Firstly, the follow-up period in our study was relatively short, spanning only six months. Dental implants typically require evaluation over much longer periods to assess their long-term success and stability accurately. Future research should include extended follow-up periods to capture late complications and ensure durability of outcomes.

Additionally, the imaging techniques used in our study warrant consideration. While radiovisiography (RVG) was chosen for its cost-effectiveness and sufficient imaging capabilities, it may not offer the same level of detailed three-dimensional visualization as cone beam computed tomography (CBCT). CBCT could potentially provide more comprehensive insights into crestal bone changes and implant positioning, which are crucial for evaluating long-term outcomes.

Lastly, the non-significant differences observed between groups indicate trends rather than definitive conclusions. The study's modest sample size may have affected the ability to achieve statistical significance, highlighting the requirement of substantial studies with bigger sample sizes to authenticate these trends effectively.

While our study contributes valuable insights into dental implant protocols, these limitations underscore the importance of further research with extended follow-up periods, advancedimaging techniques, and larger sample sizes to provide more conclusive and applicable findings.

FUTURE SCOPE

The promising results of ultraviolet (UV) photofunctionalization in enhancing soft tissue healing and crestal bone levels surrounding dental implants open several avenues for future research and clinical advancements in prosthodontics. First, longitudinal researches having bigger sample sizes and extended follow-up periods are essential to assess the durability of photofunctionalized implants' benefits, particularly in maintaining crestal bone levels beyond the first year post-loading. Investigating the long-term impact on peri-implantitis incidence and implant survival rates will further validate its clinical efficacy.

Second, exploring the application of UV photofunctionalization across diverse patient populations, including those with compromised health conditions like diabetes or osteoporosis, could elucidate its effectiveness in challenging clinical scenarios. This may guide tailored protocols for high-risk patients, enhancing implant success rates.

Third, research should focus on optimizing UV treatment parameters, such as exposure duration and intensity, to maximize surface hydrophilicity and cellular responses without compromising titanium integrity. Integrating photofunctionalization with emerging implant materials, such as zirconia or hybrid surfaces, could further enhance osseointegration and soft tissue integration.

Additionally, investigating the role of photofunctionalization in immediate loading protocols could streamline prosthodontic workflows, reducing treatment times while maintaining outcomes. Comparative studies with other surface modification techniques, like plasma spraying or laser etching, could establish UV photofunctionalization's relative efficacy and cost-effectiveness.

Finally, developing portable, chairside UV photofunctionalization devices could make this technology more accessible in clinical practice, enabling real-time surface treatment. This would align with the growing demand for minimally invasive, efficient prosthodontic solutions, possibly establishing a new benchmark for patient satisfaction and implant performance.

SUMMARY

This split-mouth study compared photofunctionalized and non-photofunctionalized immediate implants to evaluate their impact on soft tissue healing and crestal bone levels. UV photofunctionalization modifies titanium implant surfaces, enhancing hydrophilicity and cellular responses like attachment, proliferation, and mineralization, thus improving osseointegration and soft tissue integration. The study avoided primary closure to minimize tissue tension and complications, focusing on the soft tissue seal's role in preventing bacterial infiltration and peri-implantitis. Results showed that photofunctionalized implants exhibited significantly faster soft tissue healing and crestal bone gain compared to bone loss in non- photofunctionalized. Photofunctionalization reduced bacterial adhesion and inflammation, promoting a robust peri-implant mucosal seal and super osseointegration with near 100% bone-to-implant contact. These findings suggest UV photofunctionalization enhances implant success by improving healing and bone preservation, indicate the dawn of a new era in implantology.

CONCLUSION

This study underscores the transformative potential of ultraviolet (UV) photofunctionalization in amplifying dental implant outcomes, particularly in immediate implant placement scenarios. By altering titanium implant surfaces to a superhydrophilic, positively charged state, photofunctionalization significantly improves soft tissue healing and crestal bone stability compared to non-photofunctionalized implants. The split-mouth study design revealed that photofunctionalized implants achieved superior soft tissue healing, with healing progression rates of 33.709% by day 3, 51.065% by day 6, and 79.734% by day 15, compared to 32.478%, 43.852%, and 61.612% for non-photofunctionalized implants, respectively. These results indicate faster and more robust soft tissue integration, critical for establishing a peri-implant mucosal seal that protects against bacterial infiltration and peri-implantitis.

Moreover, photofunctionalized implants exhibited a remarkable mean crestal bone gain of 0.53mm after 6 months.. This bone preservation is attributed to enhanced osseointegration, with bone-to-implant contact approaching 98.2%, reduced soft tissue interposition, and decreased bacterial adhesion. These findings align with the concept of "super osseointegration," where photofunctionalized implants foster rapid bone formation and stress distribution, mitigating marginal bone loss.

UV photofunctionalization represents a paradigm shift in implantology, offering a non-invasive, topography-independent method to optimize implant performance. By promoting soft tissue healing, reducing inflammation, and enhancing bacterial resistance, this technique sets a new standard for achieving long-term implant success and patient satisfaction in prosthodontic practice.

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ANNEXURE I

SANTOSH
Deemed to be University
(Established u/s 3 of the UGC Act, 1956)

F. No. SU/2023/2480[1] Dated: 26.09.2023

Subject: Grant of Ethical Clearance for Thesis Protocol Topic "A Clinical Study to compare soft tissue healing and crestal bone levels as influenced by photofunctionalization of implants", submitted by **Dr. TRISHA VERMA,** MDS student of Batch 2022-2023, Department of **PROSTHODONTICS AND CROWN & BRIDGE**.

*****

With reference to his/her request for grant of Ethical Clearance for the Thesis Protocol entitled " A Clinical Study to compare soft tissue healing and crestal bone levels as influenced by photofunctionalization of implants", **Dr. TRISHA VERMA** is informed that the Thesis Protocol submitted by him/her was considered by the **Screening Committee** of the Santosh Dental College & Hospital in its meetings held on 07.02.2023 & 08.02.2023. The recommendations of the **Screening Committee** were considered in detail by the Institutional **Ethics Committee** in its meeting held on **23.09.2023** and the same was **approved** by the **Ethics Committee**.

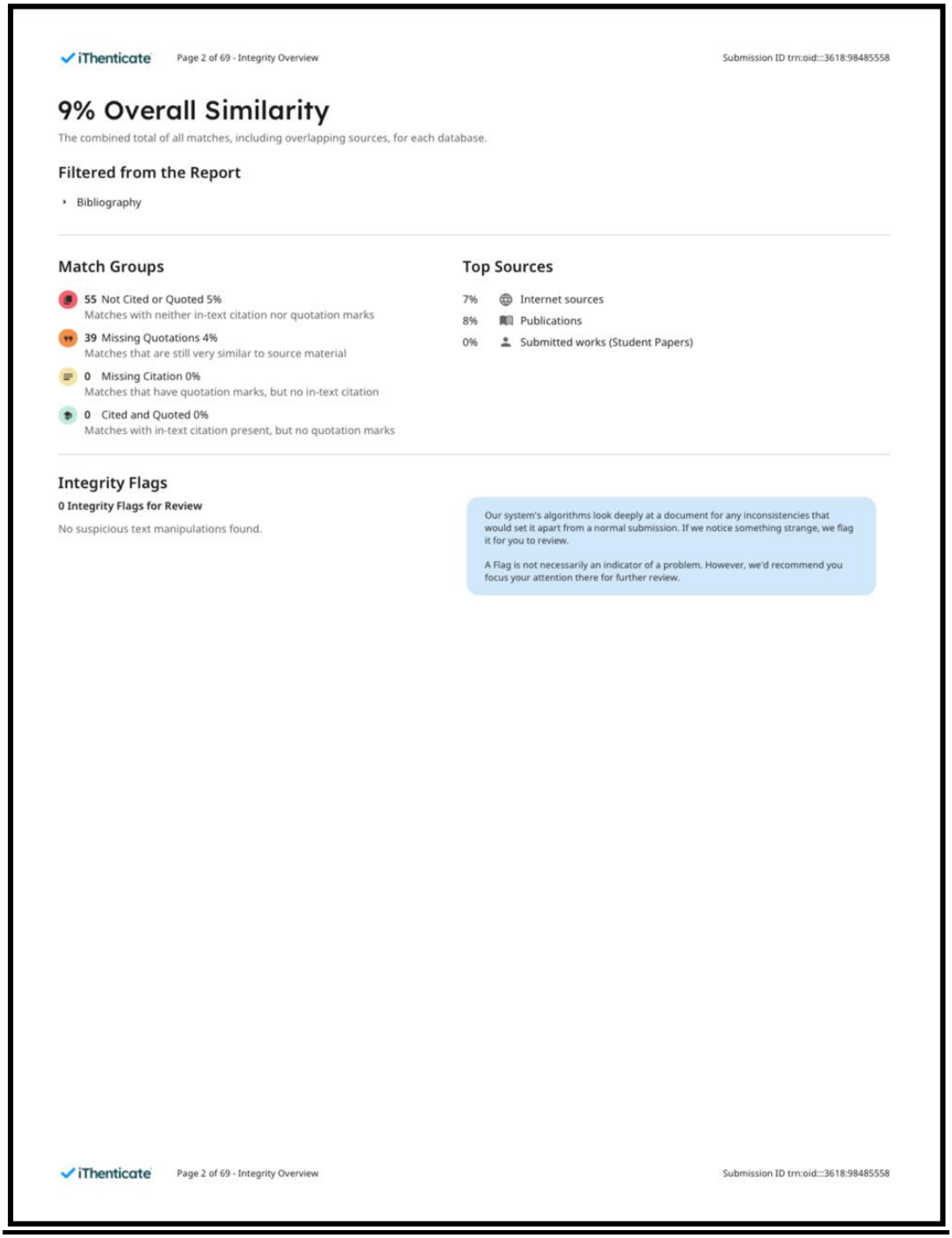
He /She is informed accordingly for further necessary action.

[DR. NARESH SHARMA]
REGISTRAR

Dr. TRISHA VERMA
MDS student of batch 2022-2023
Department of PROSTHODONTICS AND CROWN & BRIDGE
Email: trishaa.vermaa@gmail.com

Copy to:
1. The Vice Chancellor
2. The Dean, SDC&H
3. The Dean – Research
4. The Dean – Academics
5. The Director - IQAC
6. **Dr. Akshay Bhargava** (Guide)
7. HOD of **PROSTHODONTICS AND CROWN & BRIDGE**

ANNEXURE II



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ANNEXURE III

CERTIFICATE OF STATISTICAL ANALYSIS

Date: 21/05/2025

This is to certify that I have carried out the statistical analysis of the dissertation conducted by Dr. Trisha Verma, Dept. of Prosthodontics and Crown & Bridge, Santosh Dental College and Hospital titled **"A Clinical Study to Compare Soft Tissue Healing aAnd Crestal Bone Levels as Influenced by Photofunctionalization of Implants"**. The results are authentic to the best of my knowledge and belief.

Digitally signed by

Ashish Singla

Dr. Ashish Singla

M.D.S. (Public Health Dentistry)

ANNEXURE IV

DEPARTMENT OF PROSTHODONTICS AND CROWN & BRIDGE
SANTOSH DENTAL COLLEGE AND HOSPITAL
SANTOSH deemed to be University, Ghaziabad

Case History of oral and Prosthodontics examination for implant supported fixed partial/complete denture patients.

Regd. No. : **Date :**

Name: **Age/Sex :**

Telephone No. : **Occupation :**

Educational Status : **Referred By :**

Address :

Chief Complaint. :-

History of Present Illness:-

Dental History
- **Any other dental Treatment –**
- **Habits : Chewing / Parafunctional / Brushing / Any other :**

Medical history:-
- **Infectious Disease**
- **Previous reaction to drug**
- **Cardio-vascular**
- **Diabetes**
- **Any other**

Patient Psychology :

CLINICAL EXAMINATION

A. EXTRAORAL EXAMINATION

a. Facial Symmetry

b. Facial Midline

c. Smile line

d. Perioral inspection

e. visibility

B. INTRAORAL EXAMINATION

a. **Oral hygiene**

b. Periodontal Condition

c. DMF (Decayed Missing Filled)

d. Edentulous Ridge / Space

I. Span, Member and relation

II. Occluso cervical height

III. Evidence of any pathology

IV. Type of edentulous ridge

C. EXAMINATION OF PROSPECTIVE IMPLANT SITE

1. Soft tissue
   I. Lips
   II. Floor of mouth
   III. Palate
   IV. Tongue

2. Hard tissue
   I. Completely edentulous arches
   II. Partially edentulous arches

3. Perio exam
   I. Periodontal condition-
   II. Periodontal diagnosis-
   III. Periodontitis –

4. Implant site

Bone morphology_____

Previous restoration and prosthesis (Crown / FPD / RPD)

_____

D. TMJ / OCCLUSION EVALUATION

1. Any evidence of clicking, crepitation or limitation of movement

_____

2. Para functional jaw activity _____

3. Facets of wear _____

E. INVESTIGATIONS

A. Radiograph

OPG_____

CBCT_____

RVG_____

B. Systemic examination

CBC_____

HbA1c_____

C. Diagnostic cast

Span Length

_____

Occluso-Gingival Dimension

_____

Curvature of arch

_____

D. Occlusal Analysis

Wear facets (No and Size)

_____

F. TREATMENT PLANNING

Implant specifications

I. **Applied Torque**_____

II. **Implant stability**_____

No. of implants	Implant length	Implant diameter

Sl. No.	Implant specs	Sticker if any

Sl. No.	Implant specs	Sticker if any

i. Any other treatment prior to restoration
ii. Design
iii. Material
iv. Shade

F. Prognosis_____

Name and Signature
of Supervisor
Date :-

Name and Signature
of Operator
Date :-

DEPARTMENT OF PROSTHODONTICS AND CROWN & BRIDGE
SANTOSH DENTAL COLLEGE AND HOSPITAL
SANTOSH deemed to be University, Ghaziabad

PATIENT 's NAME :- O.P.D. No.:-
OPERATOR's NAME :- DATE :-

SL. NO.	DATE	WORKDONE	NEXT APPOINTMENT	SIGN
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				

ANNEXURE V

CONSENT FORM

Department of Prosthodontics and Crown & Bridge

1. I___, age_____son/daughter of_____R/O_____gives full consent for the examination, investigation and the treatment, without any compulsion of any kind.
2. I have been informed and I understand the purpose and the nature of the implant surgery procedure. I understand what is necessary to accomplish the placement of the implant under the gum and in the bone.
3. My doctor has carefully examined my mouth. Alternatives to this treatment have been explained. I have tried or considered these methods, but I desire an implant to help secure the replaced missing teeth.
4. I have further been informed of the possible risks and complications involved with surgery, drugs, and anesthesia. Such complications include pain, swelling, infection, and bruising. Numbness of the lip, tongue, chin, cheek, or teeth may occur. The exact duration may not be determinable and may be irreversible. Also possible inflammation of a vein, injury to teeth present, bone fractures, sinus penetration, delayed healing, and allergic reactions to drugs or medications used may occur.
5. I understand that if nothing is done, any of the following could occur: bone disease, lossof bone, gum tissue inflammation, infection, sensitivity, and looseness of teeth followed by necessity of extraction. Also possible are temporomandibular joint (jaw) problems, headaches, referred pains to the back of the neck and facial muscles, and tired muscles when chewing.

6. My doctor has explained that there is no method to accurately predict the gum and the bone healing capabilities in each patient following the placement of the implant. Averagetime for an implant to integrate into the bone is 4 months for the lower jaw and 6 months for the upper jaw.
7. It has been explained that in some instances implants fail and must be removed. I have been informed and understand that the practice of dentistry is not an exact science; no guarantees or assurance as to the outcome of results of treatment or surgery can be made.
8. I understand that excessive smoking, alcohol, or sugar intake may affect gum healing and may limit the success of the implant. I agree to follow my doctor's home care instructions. I agree to report to my doctor for regular examinations as instructed.
9. I agree to the type of anesthesia used, per the choice of the doctor. If I am sedated, I agree not to operate a motor vehicle or a hazardous device for at least 24 hours or more until I have fully recovered from the effects of the anesthesia or drugs given for my care.
10. To my knowledge I have given an accurate report of my physical and mental health history. I have also reported any prior allergic or unusual reactions to drugs, food, insect bites, anesthetics, pollens, dust, blood or body diseases, gum or skin reactions, abnormal bleeding, or any other conditions related to my health.
11. I consent to photography, filming, recording, and x-rays of the procedure to be performed for the advancement of implant dentistry, provided my identity is not revealed without my further permission.
12. I request and authorize medical/dental services for me, including implants and other surgery. I fully understand that during and following the contemplated procedure, surgery, or treatment, conditions may become apparent which warrant, in the judgment ofthe doctor, additional or alternative treatment pertinent to the success of comprehensive treatment. I also approve any modification in design, materials, or care, if it is felt this is for my best interest.
13. I confirm that I have read and fully understand the above and that all blank spaces have been completed prior to my signing. I give my consent that this record can be used for research, education, training & upliftment of the dental profession.

Signature of patient: Date:

HEAD OF THE DEPARTMENT

प्रोस्थोडॉन्टिक्स और क्राउन एंड ब्रिज विभाग

1. मैं, आर/ओ का उम्र का बेटा/बेटी बिना किसी प्रकार की बाध्यता के जांच, जांच और इलाज के लिए पूर्ण सहमति देता हूं।

2. मुझे सूचित किया गया है और मैं इम्प्लांट सर्जरी प्रक्रिया के उद्देश्य और प्रकृति को समझता हूं। मैं समझता हूं कि मसूड़े के नीचे और हड्डी में इम्प्लांट लगाने के लिए क्या आवश्यक है।

3. मेरे डॉक्टर ने मेरे मुंह की सावधानी से जांच की है। इस उपचार के विकल्पों के बारे में बताया गया है। मैंने इन तरीकों को आजमाया है या उन पर विचार किया है, लेकिन मैं एक प्रत्यारोपण चाहता हूं जो खोए हुए दांतों को सुरक्षित करने में मदद करे।

4. मुझे सर्जरी, ड्रग्स और एनेस्थीसिया से जुड़े संभावित जोखिमों और जटिलताओं के बारे में भी बताया गया है। ऐसी जटिलताओं में दर्द, सूजन, संक्रमण और खरोंच शामिल हैं। होंठ, जीभ, ठुड्डी, गाल या दांतों का सुन्न होना हो सकता है। सटीक अवधि निर्धारित नहीं हो सकती है और अपरिवर्तनीय हो सकती है। शिरा की संभावित सूजन, मौजूद दांतों में चोट, हड्डी में फ्रैक्चर, साइनस पैठ, उपचार में देरी और दवाओं या दवाओं के लिए एलर्जी की प्रतिक्रिया भी हो सकती है।

5. मैं समझता हूं कि अगर कुछ नहीं किया जाता है, तो निम्न में से कोई भी हो सकता है: हड्डी की बीमारी, हड्डी का नुकसान, मसूड़े के ऊतकों की सूजन, संक्रमण, संवेदनशीलता और दांतों का ढीलापन जिसके बाद निष्कर्षण की आवश्यकता होती है। टेम्पोरोमैंडिबुलर ज्वाइंट (जबड़े) की समस्याएं, सिरदर्द, गर्दन के पिछले हिस्से और चेहरे की मांसपेशियों में दर्द, और चबाते समय थकी हुई मांसपेशियां भी संभव हैं।

6. मेरे डॉक्टर ने समझाया है कि इम्प्लांट लगाने के बाद प्रत्येक रोगी में मसूड़े और हड्डी की उपचार क्षमताओं का सटीक अनुमान लगाने की कोई विधि नहीं है। इम्प्लांट को हड्डी में एकीकृत करने का औसत समय निचले जबड़े के लिए 4 महीने और ऊपरी जबड़े के लिए 6 महीने है।

7. यह स्पष्ट किया गया है कि कुछ मामलों में प्रत्यारोपण विफल हो जाते हैं और उन्हें हटा दिया जाना चाहिए। मुझे बताया गया है और मैं समझता हूं कि दंत चिकित्सा का अभ्यास एक सटीक विज्ञान नहीं है; उपचार या सर्जरी के परिणाम के बारे में कोई गारंटी या आश्वासन नहीं दिया जा सकता है।

8. मैं समझता हूं कि अत्यधिक धूम्रपान, शराब, या चीनी का सेवन मसूड़ों के उपचार को प्रभावित कर सकता है और इम्प्लांट की सफलता को सीमित कर सकता है। मैं अपने डॉक्टर के घरेलू देखभाल निर्देशों का पालन करने के लिए सहमत हूं। मैं निर्देशानुसार नियमित परीक्षाओं के लिए अपने डॉक्टर को रिपोर्ट करने के लिए सहमत हूं।

9. मैं डॉक्टर की पसंद के अनुसार उपयोग किए जाने वाले एनेस्थीसिया के प्रकार से सहमत हूं। अगर मुझे बेहोश किया जाता है, तो मैं कम से कम 24 घंटे या उससे अधिक समय तक मोटर वाहन या खतरनाक उपकरण का संचालन नहीं करने के लिए सहमत हूं, जब तक कि मैं अपनी देखभाल के लिए दिए गए एनेस्थीसिया या दवाओं के प्रभाव से पूरी तरह ठीक नहीं हो जाता।

10. मेरी जानकारी में मैंने अपने शारीरिक और मानसिक स्वास्थ्य इतिहास की एक सटीक रिपोर्ट दी है। मैंने दवाओं, भोजन, कीड़े के काटने, एनेस्थेटिक्स, पराग, धूल, रक्त या शरीर की बीमारियों, मसूड़ों या त्वचा की प्रतिक्रियाओं, असामान्य रक्तस्राव, या मेरे स्वास्थ्य से संबंधित किसी भी अन्य स्थिति के लिए किसी भी पूर्व एलर्जी या असामान्य प्रतिक्रिया की सूचना दी है।

11. मैं प्रत्यारोपण दंत चिकित्सा की उन्नति के लिए की जाने वाली प्रक्रिया की फोटोग्राफी, फिल्मांकन, रिकॉर्डिंग और एक्स-रे के लिए सहमति देता हूं, बशर्ते मेरी अनुमति के बिना मेरी पहचान प्रकट न की जाए।

12. मैं प्रत्यारोपण और अन्य सर्जरी सहित मेरे लिए चिकित्सा/दंत चिकित्सा सेवाओं का अनुरोध और प्राधिकृत करता हूं। मैं पूरी तरह से समझता हूं कि सोची गई प्रक्रिया, सर्जरी या उपचार के दौरान और उसके बाद स्थितियां स्पष्ट हो सकती हैं, जो डॉक्टर के निर्णय में, व्यापक उपचार की सफलता के लिए प्रासंगिक अतिरिक्त या वैकल्पिक उपचार की गारंटी देता है। अगर मुझे लगता है कि यह मेरे सर्वोत्तम हित के लिए है, तो मैं डिजाइन, सामग्री या देखभाल में किसी भी संशोधन को भी मंजूरी देता हूं।

13. मैं पुष्टि करता हूं कि मैंने उपरोक्त को पढ़ और पूरी तरह से समझ लिया है और मेरे हस्ताक्षर करने से पहले सभी रिक्त स्थानों को भर दिया गया है। मैं अपनी सहमति देता हूं कि इस रिकॉर्ड का उपयोग दंत पेशे के अनुसंधान, शिक्षा, प्रशिक्षण और उत्थान के लिए किया जा सकता है।

रोगी के हस्ताक्षर: दिनांक

विभागाध्यक्ष

ANNEXURE VI

SANTOSH DENTAL COLLEGE AND HOSPITAL, GHAZIABAD
DEPARTMENT OF PROSTHODONTICS AND CROWN & BRIDGE

INSTRUCTIONS FOR THE PATIENT UNDERGOING IMPLANT SURGERY

- Bite down the gauge pack gently till the bleeding stops.
- Do not disturb the surgical area.
- Do not rinse vigorously.
- Do not smoke.
- Start salt water rinses (mix ½ tablespoon of salt in one glass of water) after 24 hours of surgery.
- Do not do strenuous activity for 2-3 days after surgery.
- Do not panic if bleeding happens after 24 hours of surgery, place a gauge pack over the area and then remove it after bleeding stops.
- Do not panic if swelling or pain starts, apply ice pack at the site. Take the medicine prescribed by the doctor to reduce swelling.
- Avoid extremely hot food and do not use a straw for the first few days of surgery.
- Avoid chewing food, for 2-3 days after surgery have luke warm liquids and pureed foods (soups, pudding, yogurt).
- Do not panic if nausea and vomiting occur, it can happen due to swallowed blood, discomfort, anesthesia.
- Do not skip the medication prescribed by the doctor.
- If any discomfort is there, do not hesitate to call your doctor.
- It is important that you should follow all the instructions given to you by the doctor for quick and better recovery

ANNEXURE VII

संतोष डेंटल कॉलेज और अस्पताल, गाजियाबाद
प्रोस्थोडोन्टिक्स और क्राउन और ब्रिज विभाग

इम्प्लांट सर्जरी से गुजरने वाले मरीज़ के लिए निर्देश

- रक्तस्राव बंद होने तक गेज पैक को धीरे से काटें।
- सर्जिकल क्षेत्र को परेशान न करें।
- ज़ोर से कुल्ला न करें।
- धूम्रपान न करें।
- सर्जरी के 24 घंटे बाद नमक के पानी से कुल्ला करना शुरू करें (एक गिलास पानी में आधा चम्मच नमक मिलाएँ)।
- सर्जरी के बाद 2-3 दिनों तक ज़ोरदार गतिविधि न करें।
- अगर सर्जरी के 24 घंटे बाद रक्तस्राव होता है, तो घबराएँ नहीं, उस क्षेत्र पर गेज पैक रखें और फिर रक्तस्राव बंद होने के बाद इसे हटा दें।
- अगर सूजन या दर्द शुरू होता है, तो घबराएँ नहीं, उस जगह पर आइस पैक लगाएँ। सूजन को कम करने के लिए डॉक्टर द्वारा बताई गई दवा लें।
- सर्जरी के शुरुआती कुछ दिनों तक बहुत ज़्यादा गर्म खाना खाने से बचें और स्ट्रॉ का इस्तेमाल न करें।
- खाने को चबाने से बचें, सर्जरी के बाद 2-3 दिनों तक गुनगुने तरल पदार्थ और प्यूरी किए हुए खाद्य पदार्थ (सूप, पुडिंग, दही) लें।
- अगर मतली और उल्टी हो तो घबराएँ नहीं, यह निगले हुए खून, बेचैनी, एनेस्थीसिया के कारण हो सकता है।
- डॉक्टर द्वारा बताई गई दवा को न छोड़ें।
- अगर कोई असुविधा हो, तो अपने डॉक्टर को बुलाने में संकोच न करें।